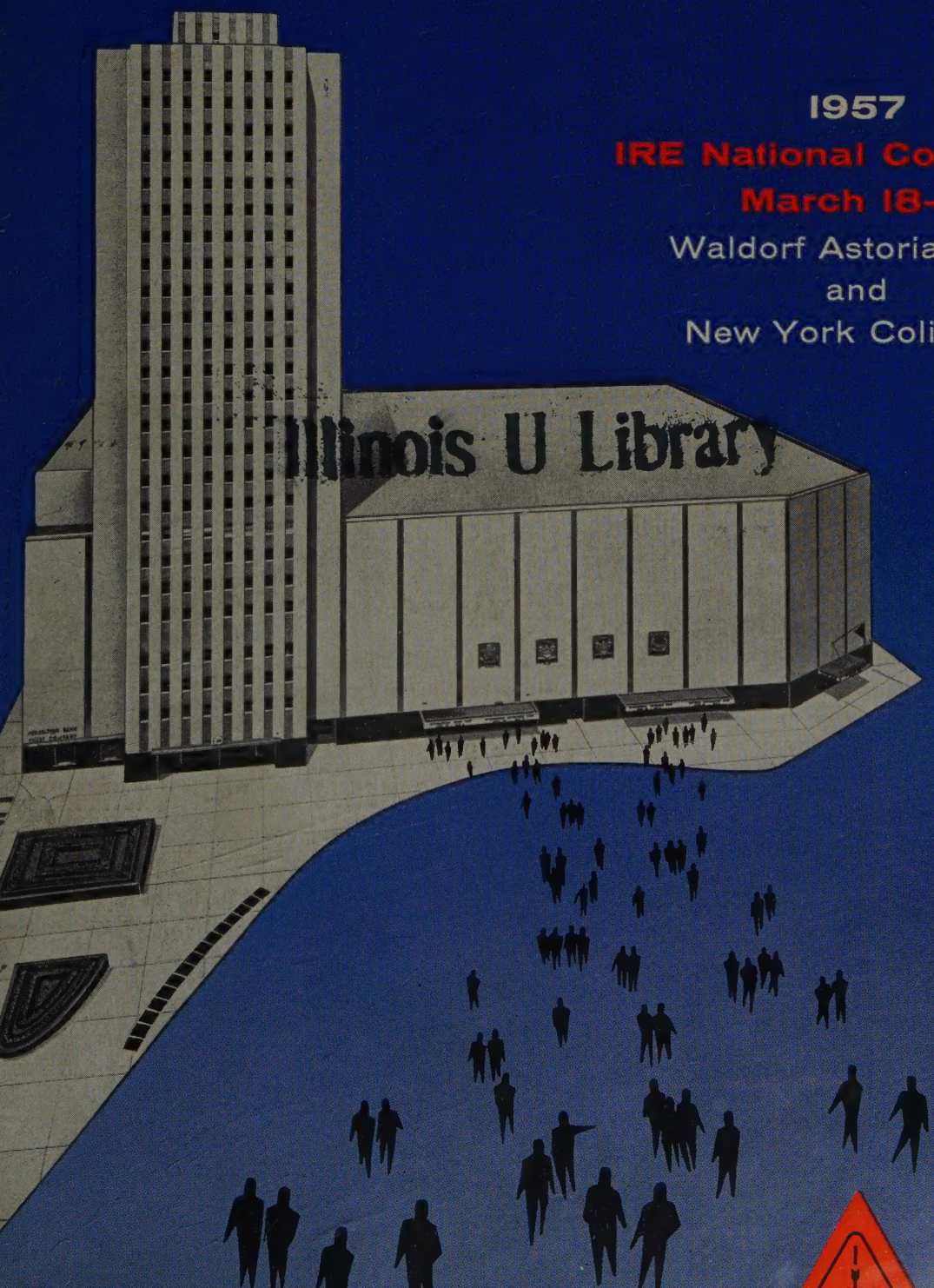
march 1957
the
institute
of
radio
engineers

Proceedings of the IRE

1957
IRE National Convention
March 18-21

Waldorf Astoria Hotel
and
New York Coliseum

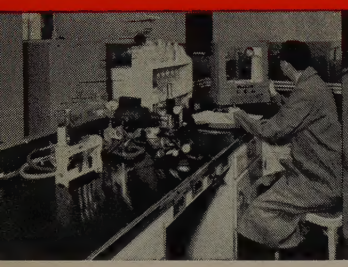


for the HIGHEST in RELIABILITY

UTC products are the most copied in the world. This is only natural, since we maintain the largest laboratories and engineering staff in our field. However copying alone cannot provide the measure of uniformity and reliability inherent in UTC units. To provide for the maximum in quality and reliability, continuing programs of quality control and quality improvement are constantly maintained in our laboratories.

WHAT MAKES A TRANSFORMER FAIL?

Illustrated are a few views of the UTC Reliability Laboratory in action... finding the answers.



Qualitative micro analysis.



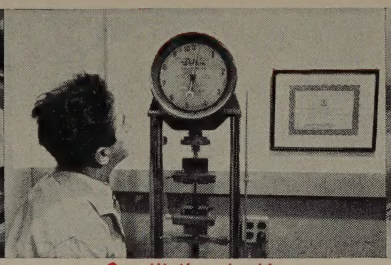
Vibration stress analysis.



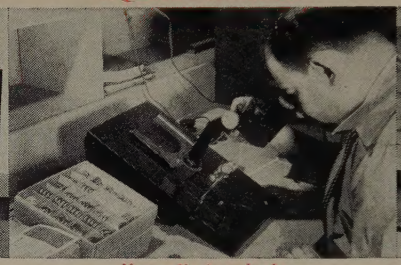
Torque testing of standard assemblies.



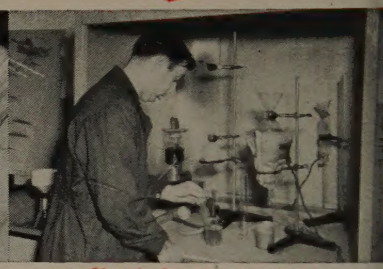
Checking uniformity of thermoplastic compounds.



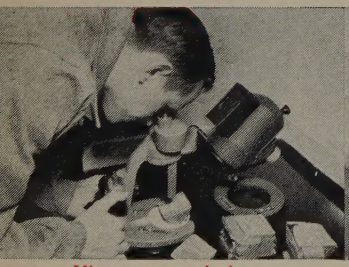
Quantitative checking of weld strength.



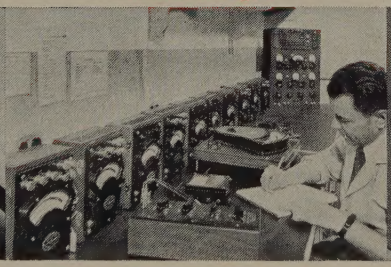
Hermetic terminals on microscope check.



Chemical section analyzing new materials.



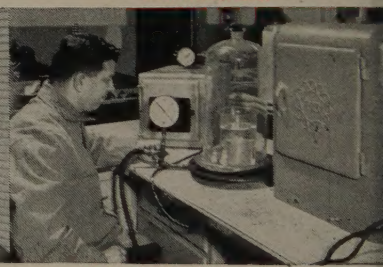
Microscope analysis of dissected units.



Calibration to primary standards.



Pilot plant hydrogen annealing.



Seal tests under extremes of cold, heat, and altitude.



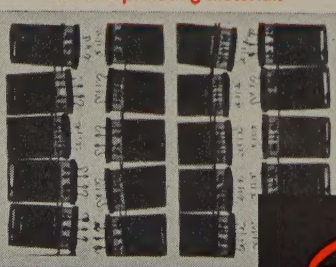
Abrasion and mercury tests on magnet wire.



Pilot plant run on encapsulating material.



Corrosion testing on insulating materials.



Non-destructive quality control by x-ray.

IS THIS PROVEN RELIABILITY AND UNIFORMITY IN THE COMPONENTS OF YOUR EQUIPMENT?

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A large instrumentation company..."We haven't had one field failure in fifteen years' use of UTC parts*."

*Over 100,000 units.

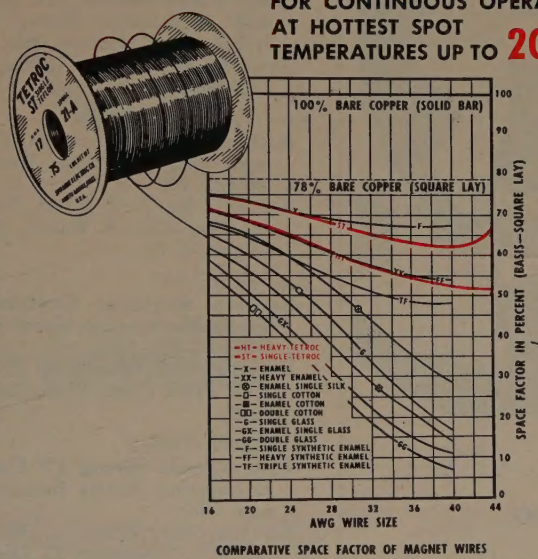
United Transformer Co.

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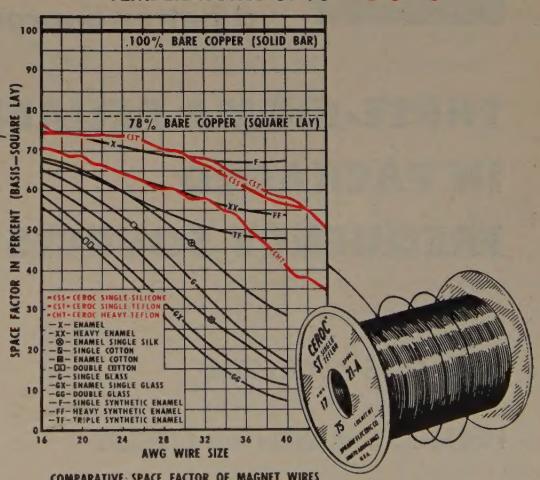


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Tetroc®

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Ceroc®



COMPARATIVE SPACE FACTOR OF MAGNET WIRES

SPRAGUE offers you a choice of 2 *truly* high-temperature magnet wires:

TETROC is recommended for continuous operation at hottest spot temperatures up to 200°C (392°F) and up to 250°C (482°F) for short periods of time. Tetroc, a teflon-insulated wire is available in both single and heavy coatings.

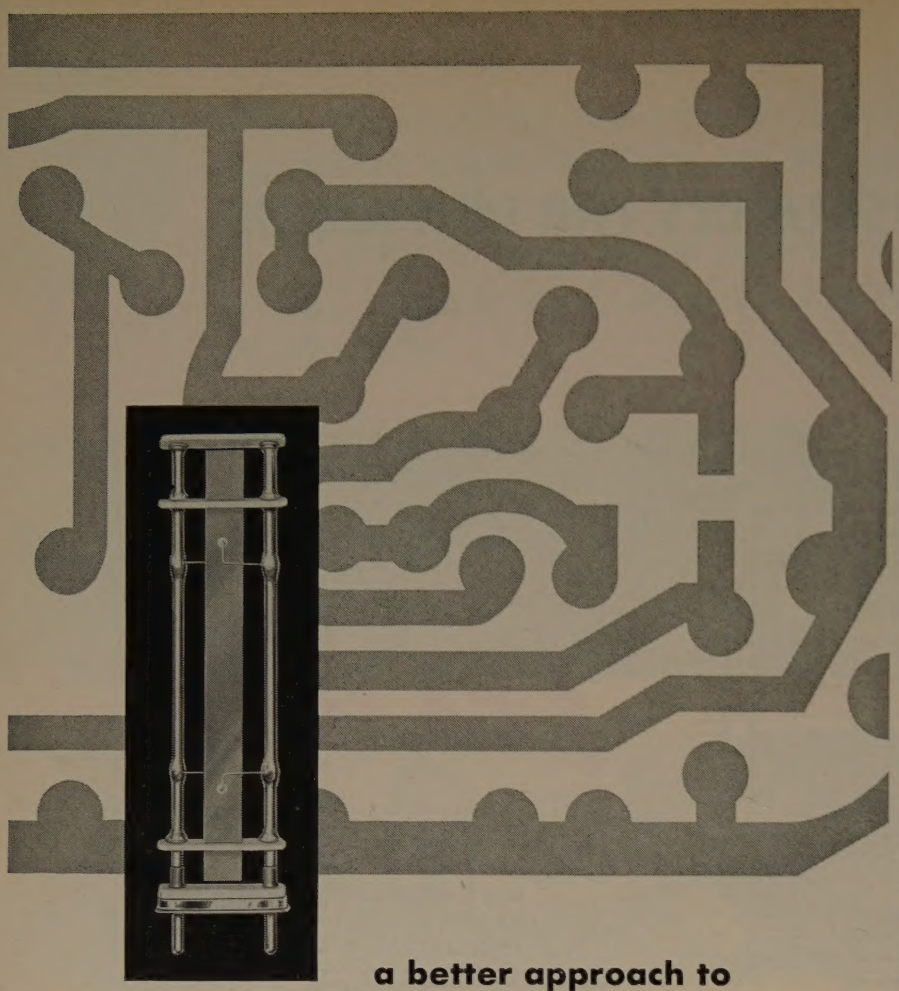
CEROC is recommended for continuous operation at hottest spot temperatures up to 250°C (482°F) and up to 300°C (572°F) for short periods of time. Ceroc wire insulation consists of a ceramic base with either single or heavy Teflon overlays—combining the best properties of both materials.

Both Tetroc and Ceroc Magnet Wires provide extremely high space factors.

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Meetings with Exhibits

● **As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups which include exhibits.**

Δ

March 18-21, 1957
Radio Engineering Show and IRE National Convention, New York Coliseum, New York, N.Y.
Exhibits: Mr. William C. Copp, 1475 Broadway, New York 36, N.Y.

April 11-13, 1957
Ninth Southwestern IRE Conference and Electronic Show, Shamrock-Hilton Hotel, Houston, Tex.
Exhibits: Mr. Karl O. Heintz, P.O. Box 1234, Houston 1, Tex.

April 14-16, 1957
National Symposium on Telemetering, New Sheraton Hotel, Philadelphia, Pa.
Exhibits: Mr. L. P. Clark, Tele-Dynamics, Inc., 32nd & Walnut Sts., Philadelphia 4, Pa.

April 24-26, 1957
Seventh Regional Conference and Trade Show, U. S. Grant Hotel, San Diego, Calif.
Exhibits: Mr. Donald E. Root, 4686½ West Point Loma Blvd., San Diego 6, Calif.

April 26-27, 1957
11th Annual Spring TV Conference, Engineering Society Building, Cincinnati, Ohio
Exhibits: Mr. Frank L. Wedig, Avco Mfg. Co., Cincinnati 25, Ohio

May 13-15, 1957
National Aeronautical & Navigational Conference, Dayton-Biltmore Hotel, Dayton, Ohio
Exhibits: Mr. Donald V. Meyers, 6962 Miami Road, Cincinnati 27, Ohio

May 20-22, 1957
Armed Forces Communication & Electronics Association, Convention & Exhibits, Sheraton Park Hotel, Washington 8, D.C.
Exhibits: Mr. William C. Copp, 1475 Broadway, New York 36, N.Y.

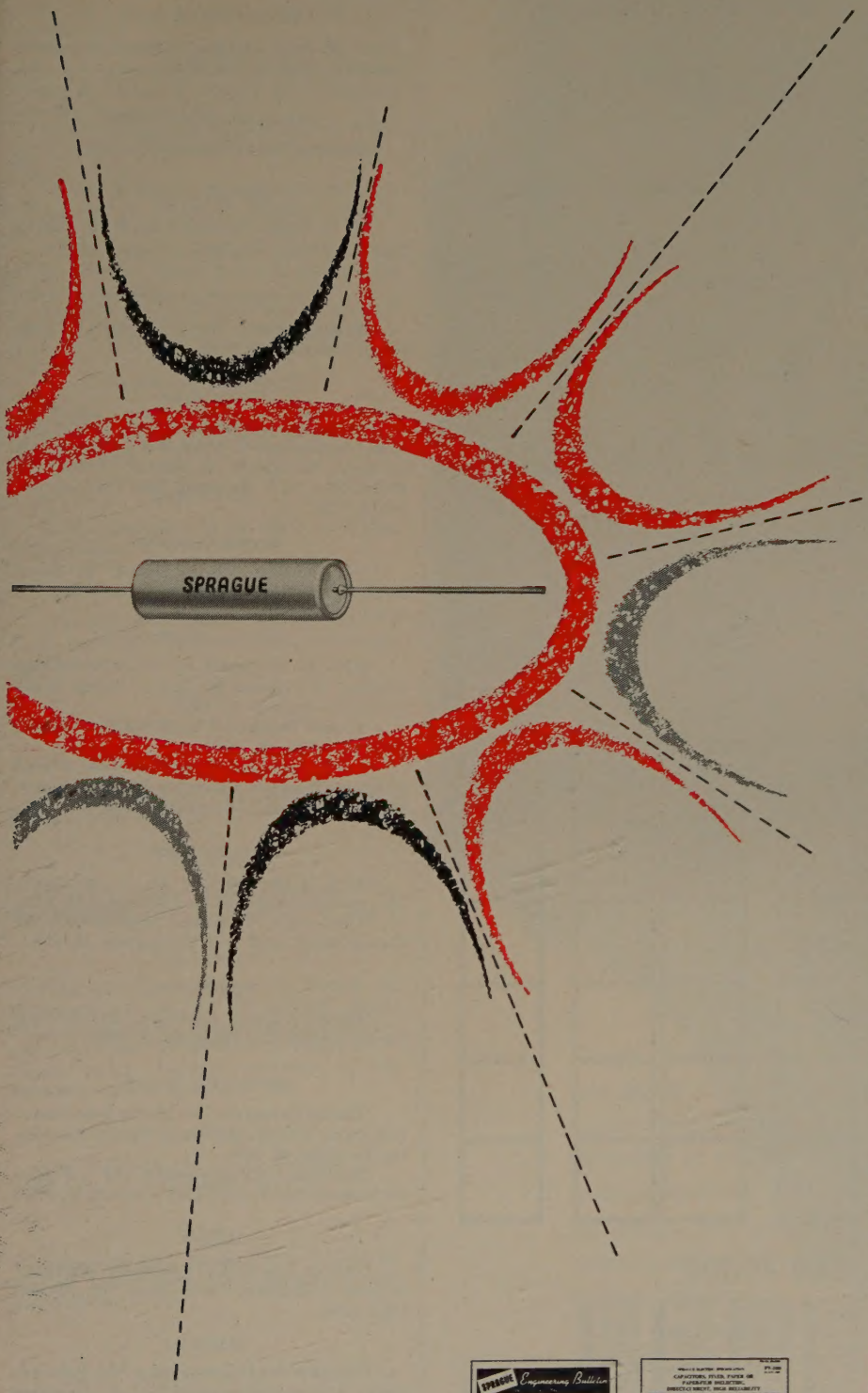
June 6-7, 1957
First Annual Conference on Production Techniques, Willard Hotel, Washington, D.C.
Exhibits: Mr. Sidney Levine, Melpar, Inc., 649 Monticello Drive, Falls Church, Va.

June 17-19, 1957
National Meeting, Professional Group on Military Electronics, Sheraton Park Hotel, Washington, D.C.
Exhibits: Mr. L. L. Whitelock, Pitt Student Union, Pittsburgh, Pa.

August 20-23, 1957
Western Electronic Show and Convention, Fairmount Hotel & Cow Palace, San Francisco, Calif.
Exhibits: Mr. Don Larson, WESCON, 342 No. La Brea Ave., Los Angeles 36, Calif.

September 4-6, 1957
Special Technical Conference on Magnetic Amplifiers, Penn Sheraton Hotel, Pittsburgh, Pa.
Exhibits: Ira Mosher Assoc., 10 Rockefeller Plaza, New York 20, N.Y.

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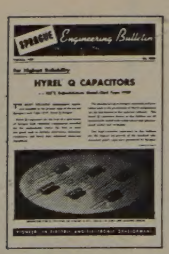


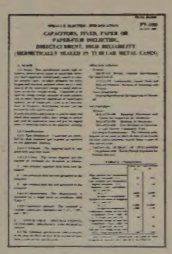
The name "Hyrel" heralds a complete new line of Sprague Capacitors conforming to the most rigorous set of capacitor specifications ever written. Techniques, materials, and processes combine to make it the most reliable paper capacitor possible within the present state of the art. After two years of exhaustive pilot runs, these high reliability units are in high volume production *now*.

In missiles, jets, warning networks, computers, controls . . . *wherever reliability is important* . . . Hyrel Q capacitors find scores of applications. A glance at Sprague Specification PV-100 tells you why. It's far above and beyond commercial or present MIL military levels . . . and it calls for outstanding performance under high *g* shock, vibration, humidity, immersion, as well as under accelerated life test. Complete facilities for making every test called for have been installed in a special plant area in which Hyrel Q capacitors are manufactured by specially selected personnel.

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Complete technical information is provided in Engineering Bulletin 2900 and Specification PV-100. Both are available on letterhead request to the Technical Literature Section, Sprague Electric Company, 235 Marshall St., North Adams, Mass.





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Section Meetings

ALAMAGORDO-HOLLOMAN

"T. V. Relay Stations," by Pete Jones, Holloman AFB; November 28, 1956.

ALBUQUERQUE-LOS ALAMOS

Christmas Party; December 21, 1956.

BAY OF QUINTE

"T. V. Studio Facilities," by W. C. Benger, Northern Electric Co., Ltd.; January 8, 1957.

BEAUMONT-PORT ARTHUR

"Semi-Conductors," by T. U. Eidson, Westinghouse; November 20, 1956.

BINGHAMTON

"Reliability of Germanium and Silicon Devices," by Maynard C. Waltz, Bell Telephone Laboratories; "Reliability of Vacuum Tubes," by Robert Moe, G. E. Receiving Tube Div.; November 19, 1956.

BUFFALO-NIAGARA

"The Handling of Noisy Signals," by Kionel Shub, Bell Aircraft Corp.; December 19, 1956.

CENTRAL FLORIDA

"SECOR—A System for Tracking Ballistic Missiles," by William P. Varson, United States Air Force; September 20, 1956.

"Project Vanguard," by G. Gridley, Patrick AFB; November 30, 1956.

"Calorimeters, Loads and New Metal Alloys," by Samuel Freedman, Chemalloy Electronics Corp.; Election of Officers; December 6, 1956.

CHINA LAKE

"Suez to the Sun," by Dr. A. M. Zarem, Electro-Optical Systems, Inc.; November 29, 1956.

"Unijunction Transistor Applications," by Conrad Neal, U. S. N. O. T. S.; December 18, 1956.

CINCINNATI

"Design for Quality and Profits," by Leon Bass, General Electric Co.; December 18, 1956.

CONNECTICUT VALLEY

"Digital Computers," by Martin Rosenbloom, Edward St. Laboratory & Linear Electron Accelerator; December 20, 1956.

"Paraballoon Antenna System," by J. W. Currie, Westinghouse Electric Corp.; January 17, 1957.

DAYTON

"Present Day Hi-Fi Loudspeaker Practices," by Louis S. Hoodwin, Electro-Voice, Inc.; December 6, 1956.

DETROIT

"The Sage Air Defense System," by Benjamin Gurley, Lincoln Laboratory of M. I. T.; December 19, 1956.

"New Adventures in Electronics," by Cyril N. Hoyler, David Sarnoff Research Center, R.C.A.; January 11, 1957.

ELMIRA-CORNING

"Automation & Education in Soviet Russia," by Dr. William H. Brandt, Westinghouse; November 1, 1956.

"Voltage Tunable Magnetrons," by Myron Weinstein, G. E. Research Labs.; November 19, 1956.

EL PASO

"See Ability," by A. D. Harrington, General Electric; January 3, 1957.

EMPORIUM

"Radioisotopes in Non-Contact Measurements," by Fred H. London, Curtiss-Wright Co.; August 24, 1956.

"The Inductronic Amplifier," by (speaker's name not provided); "Unusual Electron Tube Effects," by William E. Babcock, R. C. A., Radio Tube Div.; August 25, 1956.

"Earth Satellites and Space Travel," by Willey Ley, Consultant-Project Vanguard; September 11, 1956.

"Effects of Nuclear Radiation on Electronic Components," by Charles C. Robinson; October 16, 1956.

"An Electroluminescent Light Amplifying Panel," by Benjamin Kazan, R. C. A. Laboratories; November 20, 1956.

Movie: "Challenge of Outer Space," narration by Dr. Von Braun; Election of officers; December 11, 1956.

EVANSVILLE-OWENSBORO

"Recent Developments in the Earth Satellite Program," by Fred J. Friel, Naval Research Lab.; January 9, 1957.

FORT WAYNE

"Light Amplifiers," by Dr. Walter Grattidge, General Electric; January 3, 1957.

HAMILTON

"The Linear Accelerator—A New Tool," by C. W. Carnahan, Varian Associates of Canada; January 14, 1957.

ISRAEL

Visit to S. S. Zion; August 12, 1956.

LITTLE ROCK

Tapescript and Slides: "Fundamentals of Color Television"; December 18, 1956.

LONDON

"CFPL-TV Colour Encoding Equipment," by Glenn Robitaille, CFPL-TV; December 15, 1956.

LOS ANGELES

"Instrumentation Problems in Clinical pH Measurements," by John E. Leonard, Ph.D., Beckman Instruments; "Clinical Studies with Intragastic Electrode," by Dr. Kent L. Osmon, L. A. County General Hospital; Presentation of 1957 Fellowship Awards; January 8, 1957.

LUBBOCK

"CONELRAD," by D. F. Holaday, U. S. Government—F.C.C.; January 10, 1957.

MIAMI

Servomechanisms movie: "This is Automation," by Jackson Sells, Albert Hainlin & Associates; December 7, 1956.

MONTREAL

"TACAN," by S. H. Dodington, Federal Telephone Laboratories; January 16, 1957.

NEW YORK

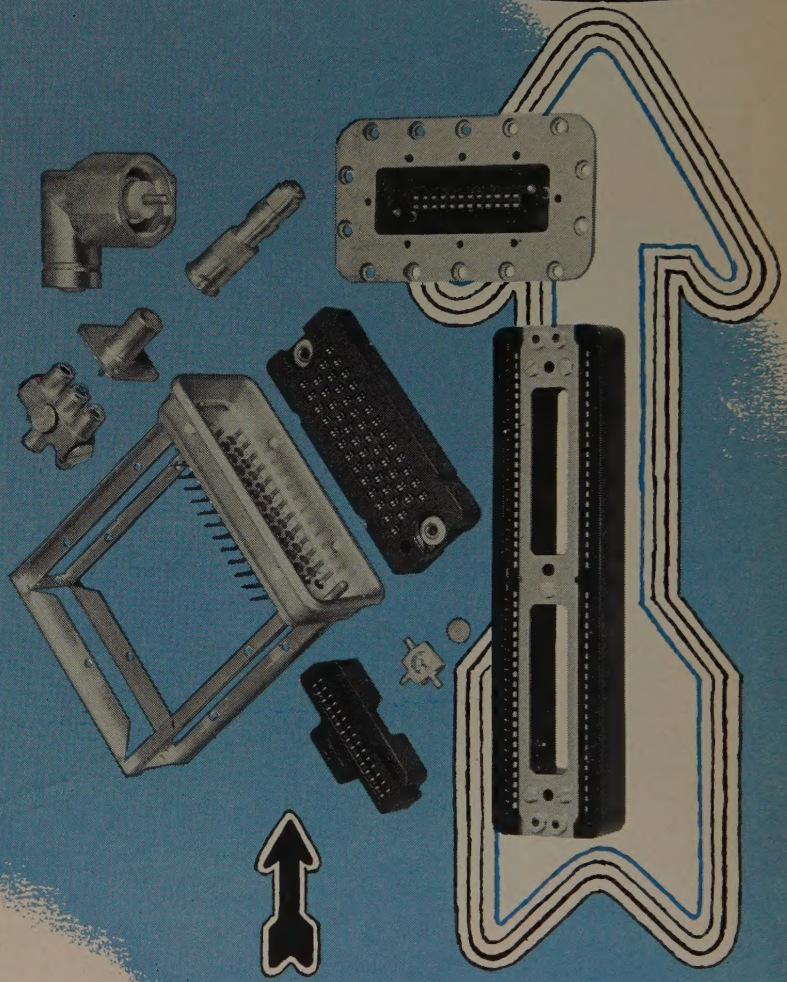
"Electronic Telephone Switching," by R. R. Dobbin, Stromberg-Carlson Co.; January 9, 1957.

NORTHERN ALBERTA

"Multiplex Equipment as Used by A. G. T.," by J. A. Barnes, Alberta Government Telephones; December 11, 1956.

(Continued on page 18A)

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Because of its operational simplicity and ultra broadband coverage, the MSG-34 will save valuable engineering and production-line man-hours.

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Inspection by X-ray, looking for deeply hidden potential faults which could cause malfunction at any time after first use.

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HIGHER carrier frequencies are covered, 4 to 540 Mc in 6 ranges.

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Frequency Range	4 to 540 Mc
Mod. Freq. Range	50 cps to 35 kc
Deviation Ranges	0 to ±5, ±25, ±75, ±125 kc
Accuracy	3%, crystal standardized
Harmonic Distortion	Less than 0.2%
Tubes	6AK5, 6C4, 6CD6, 5718, 6AL5, OB2, 5Z4G

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- Signal Generator Model 1066/1 10 to 470 Mc
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- Signal Generator Model 913 22 to 176 Mc
- Deviation Monitor Model 928 for Telemetering
- Ruggedized Deviation Monitor Model 934 2.5 to 500 Mc
- Eddystone Receiver Model 770R 19 to 165 Mc
- Eddystone Receiver Model 770U 150 to 500 Mc

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MARCONI instruments

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Section Meetings

(Continued from page 13A)

NORTHERN NEW JERSEY

"Automation and Electronics," by Richard C Marder, Malcolm Armstrong, and Gerald Walters, Stavitt Engineering Co.; December 12, 1956.

"Wide Band Communication Far Beyond the Horizon," by James Chisholm, Lincoln Laboratory; January 9, 1957.

OKLAHOMA CITY

Inspection tour of Sylvania Electric Products Company plant; December 18, 1956.

PHOENIX

"Application of Ferrites to Microwaves," by Dr. D. J. Angelakos, University of California; December 14, 1956.

PITTSBURGH

"The Vanguard Earth Satellite Program," by Leonard Arnowitz, Glenn L. Martin Company; January 14, 1957.

PORTLAND

"The Solar Battery," by C. E. Seavy. Pacific Telephone & Telegraph; November 19, 1956.

PRINCETON

"Theory and Instrumentation of Inertial Navigation Systems," by Joseph Statsinger and Bernard Litman, American Bosch Arma Corp.; December 13, 1956.

"Some Management Problems of an Industrial Research and Development Laboratory," by Dr Mervin J. Kelly, Bell Telephone Labs.; January 10, 1957.

ROCHESTER

"The Apple Color TV Display System," by Richard G. Clapp, Philco Corporation; November 15, 1956.

"New Developments in Telecommunications," by Robert R. Dobbin, Stromberg-Carlson Company; December 11, 1956.

Talk by The Right Rev. Dudley S. Stark, Bishop of the Episcopal Diocese of Rochester; December 18, 1956.

"Steering Wheels for Guided Missiles," by Lee B. Harris, General Electric Company; January 3, 1957.

SALT LAKE CITY

"50 Watt Klystron Amplifier for Microwave Relay Applications," by Rowland Haegele, Eitel-McCullough Company; October 18, 1956.

"Electronics at the University of Utah Radio Biology Laboratory," by Garth Westenskow, University of Utah; January 10, 1957.

SAN DIEGO

"Instrumental Satellites and Comets," by Dr Kraft Ericke, Convair Astronautics Div.; Election of 1957 officers; January 8, 1957.

SCHENECTADY

"Color Television," by Arthur Loughren, Airborne Instruments Laboratory; December 10, 1956.

"Nike—The Rockets Red Glare," by Howard W. Davenport, New York Telephone Co.; January 7, 1957.

SOUTH BEND-MISHAWAKA

"Recent Advances in the Art of Sound Reproduction," by Howard Southers, Electro-Voice, Inc.; December 27, 1956.

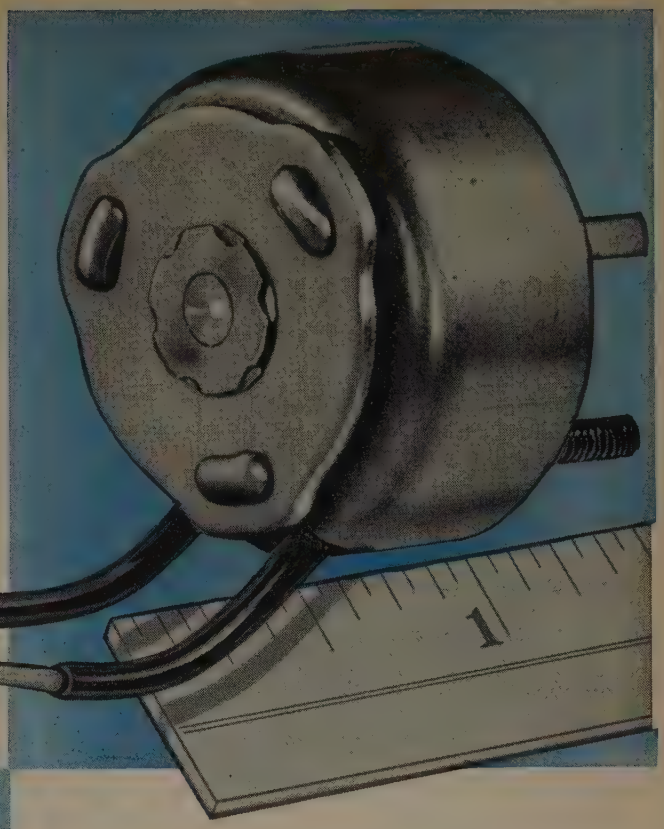
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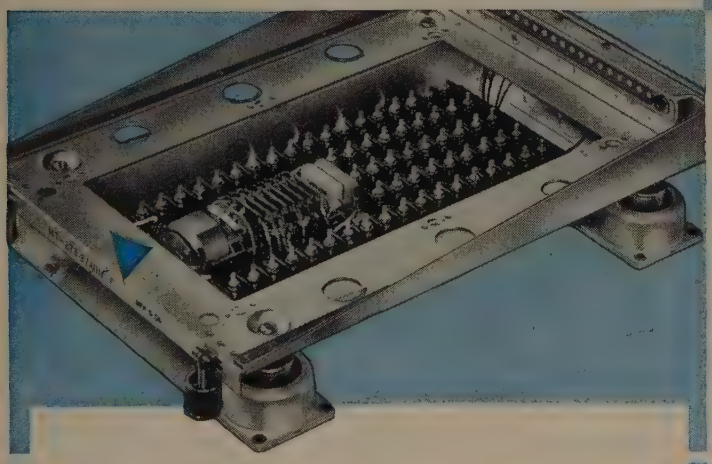
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built for you separately or in remote-controlled subassemblies







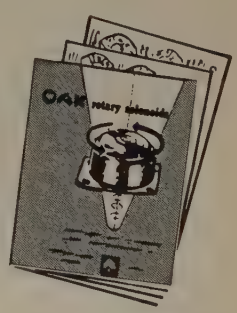
TYPICAL OAK SUBASSEMBLY WITH ROTARY SOLENOID *(MT273E BASE BUILT FOR BENDIX RADIO DIV.)*

Oak stamps, draws, welds, and etches the aluminum chassis . . . builds the rotary solenoid switch . . . manufactures the screw machine parts . . . makes the complicated cable harness . . . assembles all the parts . . . then runs life tests, heat and cold checks, and humidity chamber trials.

Oak can offer you complete engineering and manufacturing facilities for electro-mechanical subassemblies, plus a knack for making complicated devices producible. Time and again, Oak engineers have suggested changes that resulted in lower costs and better operation.

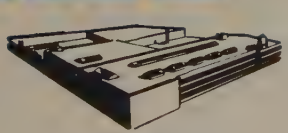
meet the most severe MIL specifications

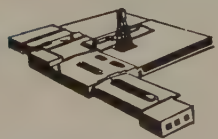
In converting a straight pull to rotary motion, Oak rotary solenoids give a high-torque, positive action, even under severe mechanical operating conditions. Oak rotary solenoids are compact, also, and help economize in wiring and mechanical linkage on remote-control devices. Three standard sizes in many variations cover a wide range of switching and light mechanical tasks. Oak also can supply *any component* needed to accompany rotary solenoids. Because Oak engineers know the application possibilities of rotary solenoids inside and out, consult them early in the design stage. They can save you valuable time. Write for a copy of Oak's rotary solenoid bulletin that includes time-saving layout sheets.



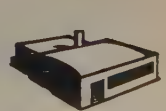
OAK MFG. CO., Dept. F, 1260 Clybourn Ave., Chicago 10, Ill.
Phone: MOhawk 4-2222

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SWITCHES • CHOPPERS • SPECIAL ASSEMBLIES • VIBRATORS • TUNERS

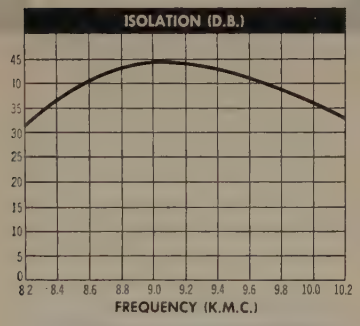
A New Broad Band Kearfott FERRITE ISOLATOR for Laboratory Test Bench Use

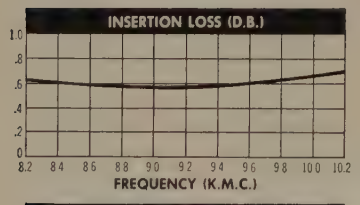


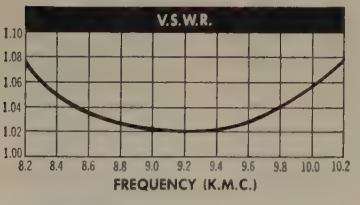
Model
W177-2C-1

Use this Ferrite Isolator in your microwave setup for maximum frequency stability.

Typical Performance Curves







CHECK THESE FEATURES:

Broad Band—Usable from 8.2 to 10.2 KMC

High Isolation—A minimum of 25 db over the band

Insertion Loss—Less than 1 db

Small & Compact—Only 2½ inches long—weighs only 1½ lbs.

Flanges—Cover type. Mates with UG39/U flanges. Will absorb up to 10 watts reflected power

Price—$135.00 each f.o.b., Van Nuys, Calif.

Delivery—From stock

Order—Model W177-2C-1

For custom-made isolators for specific radar & microwave application, you can depend on the skill of the Kearfott organization.

Kearfott, Western Division, has complete facilities for waveguide production, with qualified experts to assist in solving your problems. Let us help you.



For detailed information, ask for bulletins on new Ferrite Isolators and Radar Test sets.

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Midwest Office: 188 W. Randolph St. Chicago, Ill.
South Central Office: 6115 Denton Drive Dallas, Texas
Western Area Office: 253 Vinedo Ave. Pasadena, Calif.

Section Meetings

(Continued from page 18A)

TOLEDO

"Semi-Conductors, Rectifiers; The Old and the New," by Dr. A. E. Middleton, P. R. Mallory & Co.; December 13, 1956.

"Patents and The Protective Rights They Provide," by David H. Wilson, Marshall, Marshall, & Yeasting, and Freeman Crampton, Patent Attorney; January 10, 1957.

TORONTO

"450 MC Equipment," by G. E. S. Ayer, Canadian Marconi Company; January 14, 1957.

WASHINGTON

"U. S. A. E. C. Reactor Program," by Dr. Clark Goodman, Atomic Energy Commission; January 7, 1957.

SUBSECTIONS

BUENAVENTURA

"A Planned Approach to a High Speed Missile Camera," by Charles B. Wade, Wollensak Optical Co.; December 13, 1956.

LANCASTER

"Principles of Solar Energy Conversion," by J. J. Leferski, R. C. A. Labs.; November 13, 1956

LEHIGH VALLEY

"The Earth Satellite Program," by Dr. Homer E. Newell, Naval Research Laboratory; January 17, 1957.

MID HUDSON

"Electronics and Weather: A Partnership," by Furgeson Hall, U. S. Weather Bureau; January 15, 1957.

ORANGE BELT

"Cybernetics: Discussion of the Neural-Computer Analogy," by Dr. Norman Martin, Ramo Wooldridge Co.; "Applications of a Waveguide Slot Coupler with Unity Coupling," by R. W. Clapp, Hughes Research & Development Lab.; December 12, 1956.

PASADENA

"Infrared—The Modern Military Tool," by R. H. McFee, Aerojet-General Corp.; November 14, 1956.

"Physical Theory as the Basis for Limitations and Advantages of Transistors," by R. D. Middlebrook, California Institute of Technology; January 16, 1957.

QUEBEC

"Analog Computers," by F. Chown, Computing Devices of Canada; November 20, 1956.

"The National Research Council of Canada," by B. G. Ballard, National Research Council; November 27, 1956

SAN FERNANDO VALLEY

"The Litton Digital Differential Analyzer," by Geoffrey Post, Litton Industries; January 10, 1957.

SHREVEPORT

Tour of KTBS-TV; C. H. Maddox, Speaker, KTBS- TV; December 18, 1956.

USAFIT

"Guidance," by W. R. Boario, WADC, USAF; November 14, 1956.

NEWS and NEW PRODUCTS

MARCH 1957

Microwave Amplifier

The Amplitron, a new high-power broadband microwave amplifier tube, is announced by **Raytheon Manufacturing Co.** Microwave and Power Tube Operations, Waltham 54, Mass. It operates over a broad range of frequencies without mechanical or electrical adjustments, and may therefore be used as the output stage of a high-power broadband chain.



Developed from the magnetron oscillator, the new tube retains the magnetron's advantages—simple and compact construction, low operating voltage, and high efficiency.

The Amplitron is the only microwave tube that permits combined high-power, broadband, and coherent operation—three capabilities essential to advanced radar and counter-measures systems.

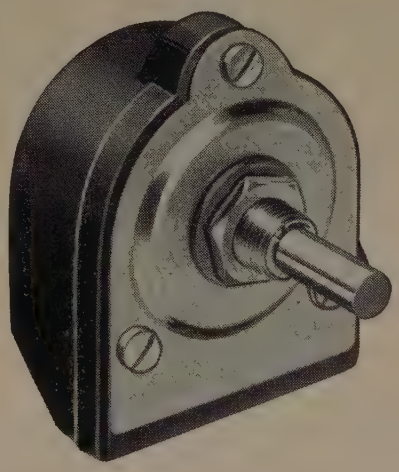
Practical applications include electronic scanning of radar beams without moving reflectors, rapid shifting of frequency to avoid rf interference, and coherent MTI systems. For example, the Amplitron is expected to lend increased capability to the air traffic control radars now being designed by Rayetheon for the U. S. and Canadian Governments.

Specifications are available from the company.

Molded Variable Resistors

Allen-Bradley Co., 136 W. Greenfield Ave., Milwaukee 4, Wisc., has just placed on the market a new 5-watt molded composition variable resistor identified as their Type H control, which is suited to industrial electronic applications.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your affiliation.



The Type H control has a maximum dc working voltage of 750 volts; a resistance range from 50 ohms to 2 megohms, and will operate effectively between temperatures of −55 and +120°. Tests show an operating life of at least 100,000 cycles with essentially no change in resistance, and equal stability of performance under conditions of wide temperatures, humidity, and voltage change. It is available with screw or bayonet terminals or solder lugs. Literature on the Type H control is available from the factory in Milwaukee.

Chassis Mounted Terminals

Terminal board breakage is claimed eliminated as a problem in the assembly and performance of a wide range of electronic gear, through the development of a line of insulated terminals announced by **Globe Electrical Manufacturing Co.,** 1729 W. 134 St., Gardena, Calif. Considered of particular importance to manufacturers of airborne electronic components, missile systems, radar, computers and other precision equipment, the insulated terminals are designed for installation directly into metal chassis.



According to Globe, its chassis-mounted terminals conform to the most advanced design trends in stringent military specifications. They are said to have high voltage breakdown range up to 15 kilovolts, high impact strength and maximum voltage range for miniaturization Standard terminals are gold-plated to faciliate soldering.

Dorr Appointed By Hathaway

Clarence J. Dorr has been appointed sales manager for Glenn M. Hathaway Electronics, Inc., 238 Main St., Cambridge, Mass., manufacturers representatives, it was announced by Glenn M. Hathaway, president. The appointment is effective January 15, 1957.



For the past two years, Dorr has been distributor sales manager for Potter & Brumfield, Inc. Prior to joining P & B he was sales manager of Sterling Engineering Co.

Dorr a native of Iowa holds a B.S. degree in electrical engineering from Iowa State College. He is registered Professional Engineer in the State of New Hampshire and has been associated with the relay industry for 30 years. He is the author of a number of articles which have appeared in various electronics trade publications and holds several patents on relays and relay applications.

Announcing the Raytheon

—a new type of broadband, high power.....



QK520
AMPLITRON
TYPICAL OPERATION (PULSED)

ANODE VOLTAGE	40 kV
ANODE CURRENT	35 amps
PEAK POWER OUTPUT	800 kw
AVERAGE POWER OUTPUT	1200 watts
EFFICIENCY	55%
OPERATING BAND (± 1 db)	1225–1350 Mc
PEAK POWER INPUT	80 kw
PHASE STABILITY WITH ANODE CURRENT	1°/amp

The Amplitron is a new type of tube developed by Raytheon, capable of power amplification at microwave frequencies. Amplification is obtained over a broad range of frequencies with no mechanical or electrical adjustments required. This device is a derivative of the magnetron and retains many of its advantages—such as high operating efficiency, construction simplicity, small size, light weight, low operating voltage. Where efficiency counts in high-power systems, the broadband Amplitron has applications of major significance.

The Amplitron uses crossed electric and magnetic fields, a reentrant beam produced by a magnetron-type cathode, and a non-reentrant broadband circuit matched at either end to external circuits.

If forward voltage drop is a problem in your diode circuitry...see the



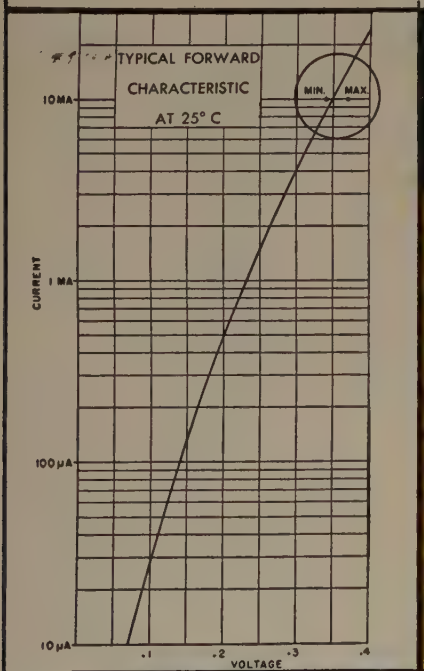
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RADIO RECEPTOR

Germanium Diode DR 385

Available now in production quantities for immediate delivery

with controlled forward voltage drop between 0.34 and 0.37V at the 10MA level



Design engineers working with transistorized circuits, computers and other applications will find that RRco. Type DR 385 has extremely low forward voltage drop as well as other desirable features. . The specifications speak for themselves!

Characteristics at 25° C

Forward voltage drop @ 10MA	
Minimum	0.34V
Maximum	0.37V
Maximum reverse current at −10V	10UA
Peak inverse voltage	60V

Maximum Ratings at 25° C

Maximum inverse operating voltage	50V
Continuous DC forward current	100MA
Surge current for 1 second	500MA
Average power dissipation	80MW
Derating above 25° C	10MW/10° C

DR 385 exhibits fast transient response and similar diodes can be offered fully tested to your recovery conditions.

In Radio and Electronics Since 1922

Further information on DR 385, or any other RRco. diode type will be sent you at once upon request to section P-3.

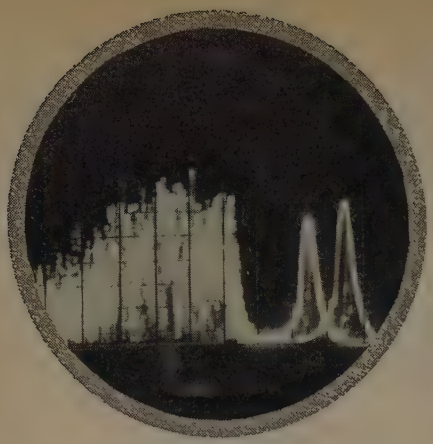
Semiconductor Division

RADIO RECEPTOR COMPANY, INC.

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Radio Receptor Products for Industry and Government: Selenium Rectifiers • Germanium Diodes Thermatron Dielectric Heating Generators & Presses • Communications, Radar & Navigation Equipment

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COMMUNICATIONS SYSTEMS ENGINEERS

The expanding scope of advanced communications projects has created several unique positions in fields related to VHF, UHF, microwave transmission and reception, forward scatter and single sideband applications at Hoffman. Electronics engineers with appropriate backgrounds will find these new assignments professionally stimulating and financially rewarding. Please write Vice President of Engineering.

I.R.E. CONVENTION
March 18th-21st

Senior Members of the Hoffman Technical Staff will be available for interview at the Convention Hotel—Please telephone EL 5-3456 for appointment.

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LABORATORIES, INC.
3761 South Hill Street
Los Angeles 7, California
Telephone: RIchmond 9-4831

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IRE People



C. W. CARNAHAN



S. R. CURTIS

C. W. Carnahan (A'34–SM'45–F'52), vice-president and general manager of Varian of Canada Ltd. since the firm's opening in October, 1955, has been appointed technical assistant to H. M. Stearns, executive vice-president and general manager of Varian Associates, at Palo Alto, Calif. Mr. Carnahan will continue as vice-president of Varian Associates' Canadian operation.

Mr. Carnahan, who is a graduate of Stanford University, also received the master's degree in physics there. He joined Varian Associates in March, 1953, as an applications engineer specializing in guided missiles after five years as electronics research manager for Sandia Corporation in Albuquerque, N. M. Mr. Carnahan previously had served in research capacities with Farnsworth Television, Hygrade Sylvania Corporation, Zenith Radio Corporation and Submarine Signal Company.

A Fellow of the Institute of Radio Engineers, Carnahan has been continuously active in IRE affairs, serving on various national committees and as chairman of the New Mexico section.

❖

Stromberg-Carlson, a division of General Dynamics Corporation, has recently announced that **S. R. Curtis** (SM'51) will become Senior Vice-President of Stromberg-Carlson. He now is Vice-President in charge of government contracts, and head of the Electronics Division.

Mr. Curtis, a native of Rochester, has been with Stromberg-Carlson since 1924, when he joined the company as a factory worker prior to graduation from Yale University. From Yale he later received a bachelor's degree in administrative engineering in 1925. He advanced rapidly through positions in purchasing, and production control departments, becoming successively purchasing agent, general superintendent, vice-president of manufacturing, vice-president and general manager in charge of the Radio-Television Division, and subsequently vice-president in charge of government contracts and head of the new Electronics Division.

He is a member of the American Society of Naval Engineers, the Armed Forces Communications and Electronics Association, and Vice-Chairman of the Military

(Continued on page 52A)

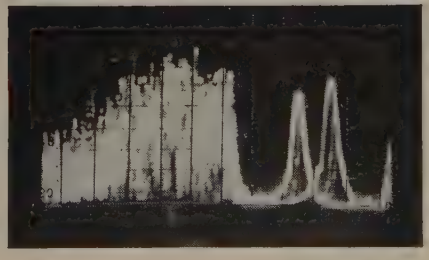


How you can "squeeze" 64 simultaneous messages into a single frequency

Breaking communication bottlenecks is a specialty of the Hoffman CV-157 Dual Sideband Converter. In one quarter the space of previous sideband converters it achieves maximum use of today's limited frequency bands, relieves traffic overloads. The CV-157, designed and developed by Hoffman, receives independently modulated AM signals with a highly suppressed carrier and splits them into two sidebands. Result: up to 75% greater effective range without increasing transmitter power—2 to 32 times more traffic capacity without increasing frequency bandwidths. As many as 64 dualtone teletype channels, or various combinations of teletype, facsimile and AM voice can be handled by the CV-157. Write today for additional data on this and other advanced communications techniques now under evaluation at Hoffman.

Scope pattern taken from Hoffman CV-157 showing two dualtone teletype channels on upper sideband, carrier partially suppressed. Each sideband can carry 32 teletype channels at one time.

One AM voice channel (made by continuous vowel sound) on each sideband, carrier completely suppressed. CV-157 carries two 3KC voice channels on each sideband.



AM voice on lower sideband, dualtone teletype channel on upper. With suitable multiplexing equipment, the CV-157 handles 64 simultaneous dualtone teletype channels.

ALL PHOTOS UNRETOUCHED FROM PANALYZOR MODEL SB-8

Electronics and Mechanical Engineers

Significant developments at Hoffman in the fields of VLF, HF, VHF, UHF, forward scatter and tropospheric communications, single sideband and advanced ECM techniques have created important positions for engineers of high calibre. Please address inquiries to Vice-President of Engineering.

Hoffman LABORATORIES, INC.

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ACEPOT*
ACETRIM*

Sub-Miniature Potentiometers and Trimmers

½" size, precision wire-wound, up to 250K, ±.3% linearity



setting *new* standards for *dependability* in sub-miniaturization

Let the facts speak for themselves! ACE Sub-Miniature Precision Wire-Wound Potentiometers and Potentiometer Trimmers are the result of 4 years development and over a year of successful use by leading electronic equipment manufacturers. Users have conclusively proved that ACEPOTS and ACE-TRIMS meet requirements for space and weight saving compactness, while at the same time meeting MIL specs' most stringent qualifications for performance and *dependability*. Why invite trouble with untested components when you can *protect your reputation with* ACEPOT and ACETRIM . . . the subminiature potentiometers and trimmers proved in actual use.

Condensed Engineering Data

	ACEPOT (potentiometer)	ACETRIM (trimmer)
Resistance Range	200 ~ to 250K ± 2%	10 ~ to 150K ± 3%
Linearity	±.3%	±3%
Resolution	extremely high	excellent
Ambient Temperature	−55° C to 125° C*	−55° C to 125° C
Torque	low or high	low or high

The above specifications are standard — other values on special order.

Available in threaded bushing, servo, flush tapped hole or flange mounting, and ganged units. All units sealed, moistureproofed, and anti-fungus treated. Meet applicable portions of JAN specs and MIL-E-5272A standards.

***New X-500 ACEPOT operates to a *new* high of 150° C.**

Expedited delivery on prototypes; prompt servicing of production orders. Send for Fact File and application data sheets.

*trademarks applied for

ACEPOT*
ACETRIM*

ACE ELECTRONICS ASSOCIATES

Dept. IR, 101 Dover St. • Somerville 44, Massachusetts

See the newest and latest at Booth 1807, the IRE Show

IRE People

(Continued from page 50A)

Products Division of the Radio-Electronics-Television Manufacturers' Association.

❖

At a recent meeting of the New York Chapter of the Armed Forces Communications and Electronics Association the following were among officers elected: **E. C. Carlson** (A'55), vice-president; **Lt. Col. David Talley** (A'35–SM'45), secretary; **Rear Adm. S. F. Patten** (M'50–SM'50), member of the executive committee; **G. W. Bailey** (A'38–SM'46–F'56), **Col. T. L. Bartlett** (M'52), **J. V. L. Hogan** (A'12–M'12–F'15), **F. R. Lack** (A'20–F'37), **Col. J. Z. Millar** (A'30–SM'45–F'56), **Col. T. H. Mitchell** (SM'45), and **Rear Adm. E. W. Stone** (A'14–M'16–F'24), directors. The A. F. C. E. A. aims to maintain and improve the cooperation between the armed forces and industry in the design, production, maintenance and operation of communications, electronics and photographic equipment.

❖

The appointment of **G. W. Wallin** (A'42–M'55) as president of the newly established Electronic Products Division was announced recently by W. E. Roberts, executive vice-president of Bell & Howell Company. Mr. Wallin has been executive vice-president of the company's Three Dimension Company Division since September, 1955.



G. W. Wallin

Prior to joining Bell & Howell in 1955, Mr. Wallin was engineering vice-president of Webster-Chicago Corporation. He has also served as chief engineer for the Home Products Division of Motorola, Inc. and Traveler Radio & Television Corporation.

A graduate of Lewis Institute, he is a member of the Radio Engineers Club of Chicago.

❖

L. M. Rodgers (M'45–SM'50) has joined the Automatic Signal Division, Eastern Industries, Inc., East Norwalk, Connecticut, as Research Assistant to the Vice-President–General Manager.



L. M. Rodgers

For the past fifteen years, Mr. Rodgers had been associated with the Research and Patent Divisions of the Philco Corporation.

Mr. Rodgers is a member of the IRE Admissions Committee and Committee 17. He was

(Continued on page 54A)

new AMP wire splice team cuts costs in aircraft and electronic industries.

You are cordially invited to visit our display at the IRE show in New York City, March 18th to 21st, 1957.
BOOTHS 2427-2429

One-piece construction and precision tooling cuts application time to absolute minimum while guaranteeing perfect, permanent mechanical and electrical connections.

Three and one-half years of engineering research have developed the following features:

Color Coding of both connector and tooling
. . . assures correct matched selection of wire, splice and tooling

Rectangular center window
. . . assures positive wire depth in barrel

Inspection ports on ends
. . . assures definite braid enclosure

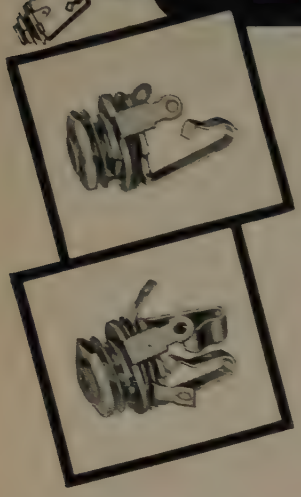


AMP INCORPORATED
General Office: Harrisburg, Pa.

Wholly Owned Subsidiaries: Aircraft-Marine Products of Canada Ltd., Toronto, Canada
Aircraft-Marine Products (G.B.) Ltd., London, England • Societe AMP de France, Le Pre St. Gervais, Seine, France • AMP—Holland N.V. 's-Hertogenbosch, Holland
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Reasons Why...

MILLIONS of SWITCHCRAFT INC. "LITTEL-JAX" Are In Use Today!



Switchcraft introduced the "Littel-Jax" in 1946. From a modest beginning, production has multiplied thousands of times.

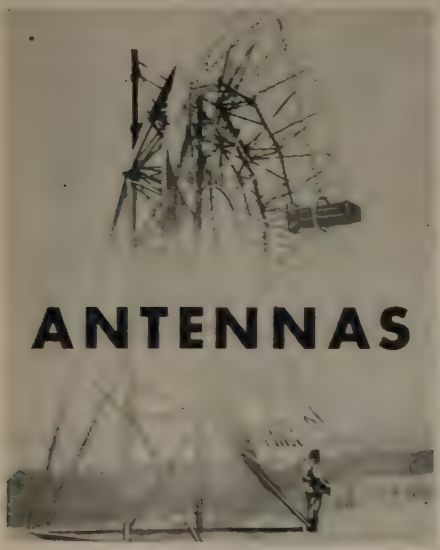
This large demand for "Littel-Jax" and hundreds of other Switchcraft components, has been the result of unique design, precision manufacturing, low unit cost and the availability of a large number of circuits.

Large daily output assures early delivery of production quantities. Stocked by leading Radio Parts Jobbers. Write for catalog S-57A.

SEE *the Complete Switchcraft Line*
and the
"MULTI-SWITCH"
BOOTH 2228
1957 RADIO ENGINEERING SHOW

SWITCHCRAFT INC. 1332 N. Halsted St., Chicago 22, Illinois

Canadian Representative: Atlas Radio Corp., Ltd., 50 Wingold Ave., Toronto, Canada.



ANTENNAS

Antennas for every need: airborne, telemetering, point-to-point, glide path, and dishes ranging from 4' to 60'. Design development and manufacture of antennas is our business. Send for technical catalog . . .

BOOTH 1428 AT
New York IRE Show

TACO
TECHNICAL APPLIANCE CORPORATION
SHERBURNE, N. Y.

IRE People

(Continued from page 52A)

President of the Philadelphia IRE Section from 1951 to 1952. He is also a member of the A.I.E.E.

Mr. Rodgers founded and served as Chairman of the Philadelphia Citizens' Committee on Traffic Control, which serves as an engineering advisory committee to the traffic engineer of Philadelphia. He was Chairman of the Transportation Committee of the Citizens' Council on City Planning in 1955 and 1956.

Mr. Rodgers is an electrical engineering graduate of Rensselaer Polytechnic Institute. He studied patent law at Columbia University and is a registered patent agent. He is a registered professional engineer in Pennsylvania, a member of the National Society of Professional Engineers and the Pennsylvania Society of Professional Engineers.

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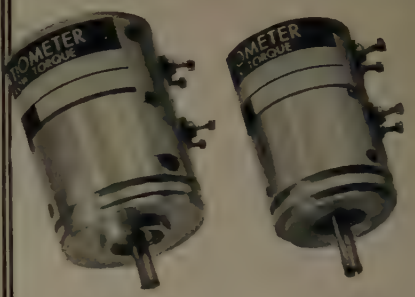
The appointment of **J. A. Marsh** (S'49–A'50–SM'53) as Vice-President of Systems Laboratories Corporation was made public recently by J. L. Barnes, President. At the same time Dr. Barnes announced that **R. H. De Lano** (A'48–SM'54), Secretary of the Corporation, had been appointed Director of the Systems Integration Division.

(Continued on page 56A)

(T) POT (R)

POTENTIOMETERS

Precision Servo Components of ULTRA LOW TORQUE



TYPE 11 *1.062" diam.*

TYPE 9 *.878" diam*

Extreme accuracy—.5% or less
Linear or non-linear characteristics
Ganged assemblies available—
up to 6 on a single shaft
Ball bearings and servo mounting
Certified performance data
furnished with each instrument

DIGITOMETER*

*Trade Mark

ANALOG-DIGITAL CONVERTER



TYPE 15

Unambiguous output—8 digits
Instruments with greater number of digits also available
Low Torque load—.25 oz. in.
Subminiature size
(weight 3.1 oz.—1.56" diam.—2.14" length)
Superprecision—±20'
Direct drive—No gears
Clockwise or counterclockwise operation
Various codes
Long life of over 5,000,000 cycles
Speeds to 650 RPM
Countless applications

For further information on other Electro-Mec instruments, contact our engineering department.

ELECTRO-MEC Laboratory, Inc.

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ELMENCO

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The Revolutionary Development In Mica Capacitors

The Dur-Mica Capacitor is a silvered mica capacitor coated with a specially developed material which provides maximum protection at environmental extremes of moisture and temperature. This combination provides a reliability and life expectancy which far surpasses anything heretofore obtained.

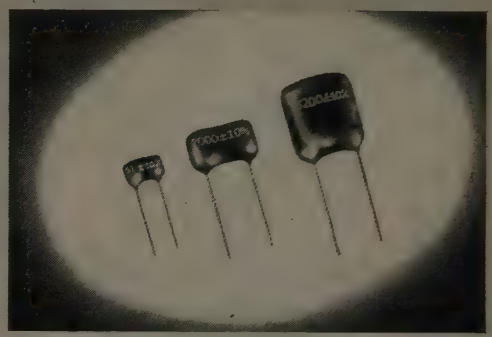
OPERATING TEMPERATURE RANGE
—55°C. to +125°C.

MINIMUM INSULATION RESISTANCE:
25000 megohms at 25°C.
1000 megohms at 125°C.

STABILITY (Capacity Drift):
±0.05% +0.1 mmf. MAX.

COMPONENT RELIABILITY

Life tests presently being performed at 125°C. and 150% rated voltage have passed 10,000 hours without a single failure. This is roughly equivalent to more than 20 years of operation under normal operating conditions.



DUR-MICA NOW AVAILABLE: DM-15, DM-19, DM-20, DM-30

ANNOUNCING a new addition to the DUR-MICA family . . . DM-42

CAPACITY VALUES UP TO:
.025 MFD.—500VDCW
.04 MFD.—300VDCW
.07 MFD.—100VDCW

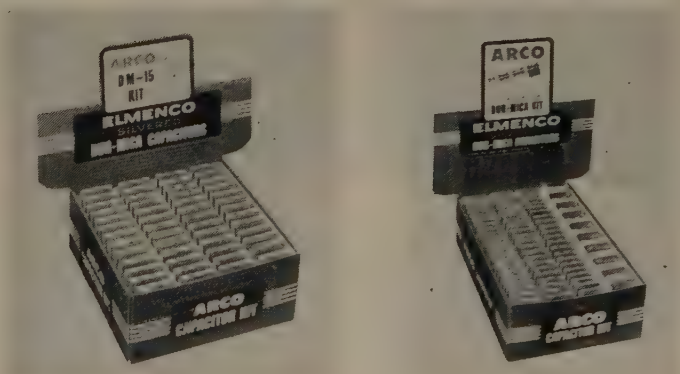
DIMENSIONS:
1½ x ⅞ x ¼

Packed in individual transparent plastic snap boxes properly identified for ease of handling.

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NEW

ARCO DUR-MICA KITS



ARCO DM-15 KIT #10

This handy DM-15 kit consists of five each of 51 capacity values from 1 mmf. to 820 mmf. Tolerance ±5%.

SPECIAL KIT LIST PRICE $95.00

If purchased individually the actual list price is $103.31.

ARCO DUR-MICA KIT #11

This Dur-Mica kit contains five each of 72 capacity values from 2 mmf. to 10,000 mmf. all 500VDCW and ±5% tolerance.

SPECIAL KIT LIST PRICE $250.00

If purchased individually the actual list price is $286.35.

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ARCO CAPACITORS INC. Los Angeles 19, Calif.
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CO-AX



★ ULTRA LOW capacitance & attenuation

TYPE	μμ F/ft	IMPED.Ω	O.D.
C 1	7.3	150	.36"
C 11	6.3	173	.36"
C 2	6.3	171	.44"
C 22	5.5	184	.44"
C 3	5.4	197	.64"
C 33	4.8	220	.64"
C 4	4.6	229	1.03"
C 44	4.1	252	1.03"

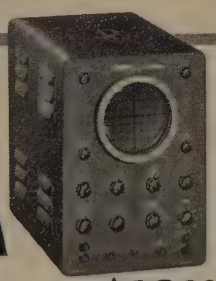
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Constant 50Ω-63Ω-70Ω impedances

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FOR LAB, SERVICE & INDUSTRIAL USE
fine electronic equipment in easy-to-build form



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- 5 Mc Width for Color TV
- Hor. Sweep to 600 Kc
- 25 mv-inch Sensitivity
- DC Positioning Controls
- Z-Axis Input

Only $69.00

Outstanding value in a quality scope, ideal for Color TV work and high-frequency lab applications. Wide sweep range from 15 to 600,000 cps. Locks in at frequencies as high as 9 mc. Only 1 db down at 3.58 color burst frequency. Vertical response: ± 3 db, 5 cycles to 5 mc. Vertical sensitivity, 25 rms mv/inch. 20 mmf input capacity. Special features: cathode-follower vertical and horizontal inputs; 2nd anode of 1400 volts for high intensity trace; p-p vertical and horizontal amplifiers; faithful square wave response; positive and negative locking for excellent synch on complex waveforms; frequency-compensated input attenuator; Z-axis input, 1-volt peak-to-peak calibrating voltage; internal astigmatism control; blanking circuit to eliminate retrace lines, etc. Complete with all tubes (including CRT), parts, punched chassis, case, full assembly instructions. Shpg. wt., 40 lbs.

Model 83 YZ 144. Wide-Band Oscilloscope Kit. Net $69.00



knight-kit
VOLTAGE CALIBRATOR KIT

Only $12.75

Permits use of any scope as a precision peak-to-peak AC voltmeter. Puts a true square-wave voltage on scope screen. Range switch and calibrated potentiometer selects any voltage between .01 and 100 volts in 4 ranges. Fifth position feeds external signal to scope for comparison. Has voltage regulator tube—output voltage stays constant with line variation from 80-135 volts. Accuracy, ± 6% on all ranges. Shunt capacitance only 15 mmf. Includes control for providing precision initial setting. Direct coupling of output provides ground reference for DC scopes. Complete kit includes all parts, case, full instructions. Shpg. wt., 5 lbs.

Model 83 Y 136. Voltage Calibrator Kit. Net $12.75

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All Prices Net F.O.B. Chicago

IRE People

(Continued from page 54A)

Dr. Marsh, a graduate of Ohio Wesleyan University who received his doctorate in electrical engineering at Ohio State University, holds three patents covering the design of monopulse radar vhf systems. Before joining Systems Laboratories he was radar group leader in the Autonetics Engineering Department of North American Aviation, where he had the direction of all missile and manned aircraft antenna designs accomplished at the Downey plant. He is a member of Phi Beta Kappa, Sigma Xi, Eta Kappa Nu and Pi Mu Epsilon.

Mr. De Lano, who received his B.S. and M.S. degrees from the California Institute of Technology, was instrumental in the development of the Falcon air-to-air guided missile as senior staff physicist at Hughes Aircraft Corp. He has conducted theoretical and analytical studies in a variety of subjects dealing with radar, missile trajectories, navigation and control systems, etc., and is the holder of two patents. He is at present chairman of the Los Angeles IRE Professional Group on Information Theory, as well as a member of Tau Beta Pi and of the Scientific Research Society of America.

❖

General Electric's laboratory operations at Electronics Park, Syracuse, N. Y., have been reorganized, it has been recently announced. The Electronics Laboratory will become a component of the Defense Electronics Division serving military product departments in Syracuse, Utica and Johnson City, N. Y., and Philadelphia, Pa. The Materials and Processes Laboratory will be transferred to the Heavy Military Electronic Equipment Department in Syracuse, N. Y. These changes became effective January 1, 1957 and both laboratories are continuing their headquarters in the laboratories building at Electronics Park.



J. B. Russell

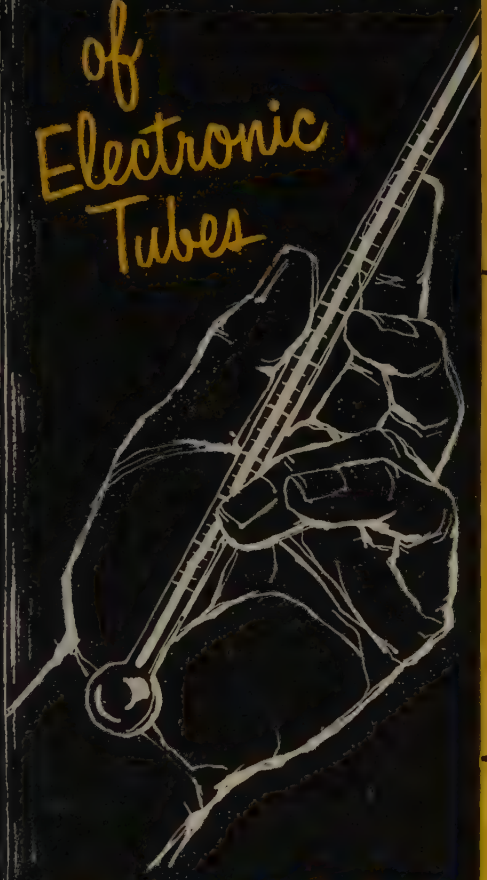
Concurrent with the organization moves, **J. B. Russell** (A'36–SM'45) was named manager of the Electronics Laboratory.

Dr. Russell had been manager of the Engineering Analysis Subsection of the Electronics Laboratory since 1955. He came to the laboratory as a consultant from Columbia University where he was head of the Department of Electrical Engineering.

A Massachusetts Institute of Technology graduate, and later a member of its academic staff, Dr. Russell joined the Columbia University Electrical Engineer-

(Continued on page 58A)

LIQUID COOLING of Electronic Tubes



WITH Eastern COOLING UNITS

By a sustained program of research, Eastern continuously extends the uses of the latest units in electronic tube cooling, pressurizing electronic equipment, and pumping fuels and hydraulic fluids. Research and testing laboratories, a model shop, and three manufacturing plants provide the specialized equipment and manpower to turn out fully qualified units to meet appropriate government specifications.

From our extensive line of existing units, adaptations of these units, or completely new designs, Eastern can provide equipment to handle your project well. Your inquiry is welcomed.

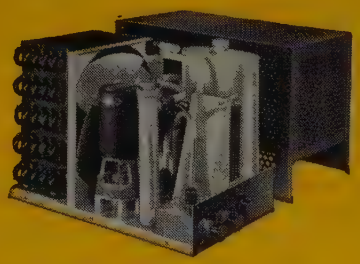
EASTERN INDUSTRIES, INC.
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HAMDEN 14, CONNECTICUT

Eastern Cooling Units provide coolant liquid for maintaining within safe operating temperature limits liquid cooled electronic tubes or similar devices. The units are completely self-contained and usually comprise such components as heat exchangers, fans or blowers, liquid pumps, reservoirs, flow switch, thermostat, etc.

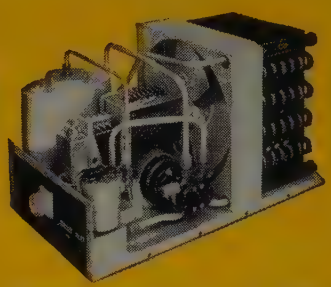
Cooling units can be modified as required for varying conditions encountered in land or sea as well as aircraft service. Almost all units are designed to meet such specification as MIL-E-5400 and MIL-E-5272.

The units shown below are intended only to illustrate the varying requirements which can be satisfied. By utilizing fairly standard components and designs based on broad experience in this field, Eastern is able to provide at minimum cost equipment exactly suiting a specific requirement.

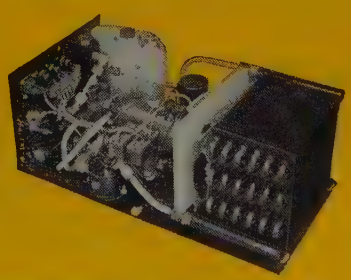
Eastern welcomes your consultation on liquid cooling problems ranging from 200 to 20,000 watts dissipation.



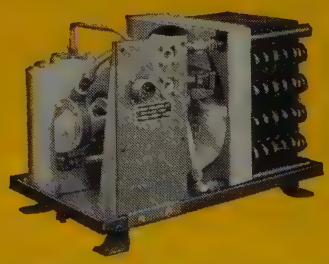
MODEL MB-175, TYPE 200 DISSIPATION: 2,000 watts. ALTITUDE RANGE: sea level to 50,000 feet. POWER REQUIRED: 28 volts D.C. WEIGHT: 25 pounds. SIZE: 10" x 15-15/16" x 10¾" high.



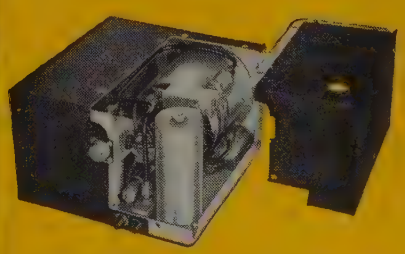
MODEL E/HT-205, TYPE 200A DISSIPATION: 1600 watts. ALTITUDE RANGE: sea level to 5,000 feet. POWER REQUIRED: 28 volts D.C. WEIGHT: 25 pounds. SIZE: 10" x 21" x 10" high.



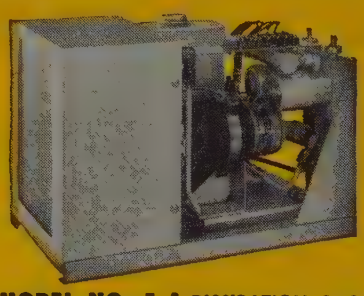
MODEL MB-177, TYPE 202 DISSIPATION: 1700 watts. ALTITUDE RANGE: sea level to 50,000 feet. POWER REQUIRED: 110 volt, 400 cycle, 3 phase. WEIGHT: 27 pounds. SIZE: 10" x 19 15/32" x 7⅝" high, per JAN-C-1720A, size B1-D1.



MODEL E/HT-210, TYPE 200 DISSIPATION: 1500 watts. ALTITUDE RANGE: sea level to 10,000 feet. POWER REQUIRED: 208 volts, 400 cycle, 3 phase. WEIGHT: 35 pounds. SIZE: 11¼" x 19½" x 12½" high.



MODEL E/HT-200, TYPE 201 DISSIPATION: 1,000 watts. ALTITUDE RANGE: sea level to 50,000 feet. POWER REQUIRED: 28 volts D.C. WEIGHT: 14½ pounds. SIZE: 10" x 10" x 6" high.



MODEL NO. 5-A DISSIPATION: 1,000 watts. ALTITUDE RANGE: sea level to 5,000 feet. POWER REQUIRED: 100 to 110 volts D.C. WEIGHT: 10 pounds. SIZE: 7⅞" x 13½" x 9-1/16" high.





IRE People

(Continued from page 56A)

ing Department in 1931, becoming a full professor in 1949 and head of the department in 1952.

For five years during World War II, he was engaged in supervising research and development work in the field of fire control, first as a technical aide to the National Defense Research Committee and then as an expert consultant in the Office of the Secretary of War.

Dr. Russell is a Fellow of the A.I.E.E. and the New York Academy of Sciences, and a member of the Association for Computing Machinery and the American Society for Engineering Education.

❖

Mal Mobley, Jr. (A'46–M'50–SM'53) has been named to the Sales Staff of the Los Angeles office of E. V. Roberts & Associates, electronic engineering representative.

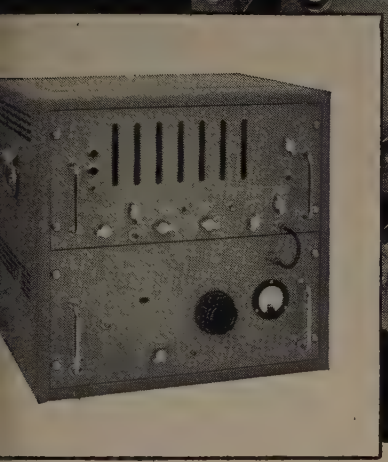
Mr. Mobley has been active in the electronic industry for the past twenty years. His activities have included sales, engineering, advertising and promotion. Prior to his present affiliation, he was manager of WESCON.

(Continued on page 60A)

SE history
umber 6

JFD Electronics

PISTON CAPACITORS AT WORK



JFD Electronics

trimmers achieve maximum measurement, accuracy and stability in BERKELEY frequency meters

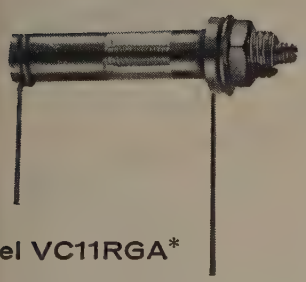
PROBLEM: To combine functions of precision wide-range frequency meter and universal counter and timer in one compact instrument—to measure frequency from 0 to 42 megacycles with an accuracy of ±1 cps or greater and elapsed time from 1 microsecond to 10 million seconds with a maximum accuracy of ±1 micosecond.

SOLUTION: *Berkeley engineers specified 22 model VC11RGA JFD Trimmer Piston Capacitors in the 0-42 mc. harmonic frequency turret to assure precise repeatable selection of reference frequencies.* The reasons *JFD Variable Trimmer Capacitors were selected? . . . Because an ultra-stable compact, trimmer capacitor was needed to afford rapid and accurate tuning capacity in the reference oscillator circuit.*

RESULT: Performance so outstanding that Berkeley, division of Beckman Instruments, Inc., has continued to specify JFD Piston Capacitors in their model 5571 Frequency Meters for 3½ years.

MORAL: If you are seeking *stability, shock-resistance, ultra-linear tuning* and *wide operating temperature range* in a trimmer capacitor, you'll find the best answer at JFD.

actual size



del VC11RGA*

-10 mmf-glass dielectric-invar rotor)

Why don't you take advantage of JFD Piston Capacitors in solving your circuit tuning problems?

**One of the miniature and subminiature JFD Piston Capacitors now serving in printed and conventional electronic circuits. Write for literature.*

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Go Forward with JFD Engineering!

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by Waterman

BOOTH NOS. 1902-1910

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OR MULTI-PURPOSE
PORTRAYAL



ANOTHER EXAMPLE OF Waterman PIONEERING...

The Waterman PANELSCOPE is a new concept in miniaturized built-in cathode ray tube oscilloscope gaining wide use as an integral part of electronic equipment. A unique design has permitted its use in commercial products, factory test stands, field trouble shooting kits, system monitors and many other applications.

The PANELSCOPE compactness (5¼" x 5-3/16" and 10" depth at 5 lbs.) is coupled with the following features:

- SIMPLICITY OF OPERATION — Can be supplied so that a twist of a single rotary switch provides a synchronized pattern of desired incoming signal (up to 9 circuits) against proper linear time base. This is ideal for monitoring and trouble shooting, as it removes the need of fiddling with knobs as is done now on general purpose oscilloscopes. The static controls, such as beam, focus, positioning, and graticule brightness, are located in tube escutcheon.
- AVAILABLE CIRCUITS — A wide variety of — signal amplifiers with response from dc to megacycles and sensitivities from 5 millivolts — synchronized or triggered linear time base generators from ½-cycle (and lower if need be) to 2 microseconds — can be specified by you to fit your needs for any particular equipment.
- FLEXIBLE DESIGN — The basic PANELSCOPE consists of the cathode ray tube and high voltage supply packaged in the standard case without the panel mounted controls. The PANELSCOPE can also be supplied fully wired and tested with chosen signal amplifier, linear time base generator and attendant sync. amplifier.
- POWER REQUIREMENT — Less than 10 watts of line power for built-in high voltage supply — The required B+ and heater current is determined by your requirements. For those cases where B+ and heater power is not available, auxiliary PANELPACK can be supplied.

There is a place in your equipment for Waterman PANELSCOPE, a custom built oscilloscope at production prices, although your needs may be for but one or many. A Waterman representative will help you fit a Panelscope to your requirements.

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POCKETSCOPE*
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RAYONIC* Cathode Ray Tubes
and Other Associated Equipment

*T.M. REG.



IRE People

(Continued from page 58A)

Martin Kaplan (S'52–A'53–M'55) has been advanced to Assistant Sales Manager, Electronic and X-Ray Division of F-R Machine Works, Inc. of Woodside, N. Y.



MARTIN KAPLAN

Mr. Kaplan has been associated with the firm for the past three years, first as a Microwave Test Equipment design and development engineer and more recently as a Sales and Application Engineer. He was graduated in 1954 with the M.S. degree in Electrical Engineering from Newark (N. J.) College of Engineering, majoring in microwave communication. He also holds the B.A. degree in Mathematics from New York University.

Mr. Kaplan's technical background includes the design and development of many types of waveguide components and test equipment and applied research on dummy loads, as well as specification writing and analysis. As a sales engineer, he has been responsible for demonstration and application engineering of microwave test equipment, as well as other administrative activities in the sales department. He is a Member of the I.R.E., and an Associate Member of the A.I.E.E.

✣

John Jipp (A'44–M'46) of Ampex Corporation, Redwood City, California, has been appointed manager of the firm's Instrumentation Division, moving up from the post of marketing manager, which he had held since joining Ampex in November, 1953.



JOHN JIPP

Before coming to Ampex, Mr. Jipp was Southwestern regional sales manager for Motorola, Inc., and he established and managed Motorola's West Coast parts and service depot. His work during World War II included design engineering and field research on military radio equipment with the Signal Corps laboratories.

Mr. Jipp has completed post-graduate work in marketing and managerial economics at the University of Chicago, and he is a member of the National Sales Executives, Society of American Military Engineers, Armed Forces Communications Association, and the American Management Association.

In his new assignment, Mr. Jipp will be in charge of Ampex instrumentation recorder research, development and marketing.

(Continued on page 62A)

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April eleventh through April thirteenth

Nineteen hundred and fifty-seven

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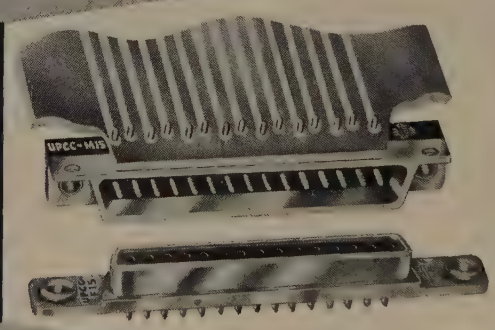
FOUR-CHANNEL OPEN-WIRE CARRIER-TELEPHONE SYSTEM.

This is a high-grade long-haul system compatible with three-channel type C, OA-11/FC and OA-12/FC systems. The fourth toll-grade channel has been obtained by advanced filter and oscillator-network design without changing the frequency allocation or degrading the performance of the three carrier channels or of the physical circuit. Transmission in one direction is in the band 3.4 kc to 15.65 kc, and in the other direction in the band 17.95 kc to 31.4 kc. On copper conductors repeater sections average 200 miles, and high-grade circuits several thousand miles in length can be maintained under all climatic conditions.

Type AN/FCC-10 Carrier-Telephone Terminal manufactured for the U.S. Army Signal Corps. This terminal includes regulated-tube rectifiers, d-c telegraph composite sets, line protectors, operator's telephone set, 4-wire terminating sets, v-f signal converter type CV-399/FCC, and all accessories to form a complete packaged 4-channel terminal. It is moisture- and fungus-proofed, and meets all applicable MIL specifications. It is a-c operated.

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PRECISION CONNECTORS for PRINTED CIRCUITRY



U. S. Components' printed card connectors embody all the design features demanded by printed circuit users. Minimum space, high-compression molded inserts, die-cast aluminum shells result in polarization flexibility and high electrical and mechanical performance even under the most severe environmental conditions.

Series UPCC connectors are available with 7, 11, 15, 19 or 23 contacts for 1/16", 1/8" and 1/4" printed card with UPCC-F (wire-solder) and UPCC-FD (board dip-solder) terminations.

Write TODAY for complete information on U.S.C. printed card connectors and receptacles and the name of nearest U.S.C.engineering representative.

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454 East 148th Street, New York 55, New York

"Pioneers in Connectability"

See us at the IRE Show—Booth 2706—2nd Floor—Components

IRE People

(Continued from page 60A)

Robert Sackman (S'48–A'51) has been elected General Manager of the Ampex Corporation in Redwood City, California. G. I. Long, President of the firm which manufactures magnetic tape recording equipment for sound, science and television uses, made the announcement recently. Mr. Sackman, already a vice-president of the firm, comes to his new position from his post as manager of the Ampex Instrumentation Division.

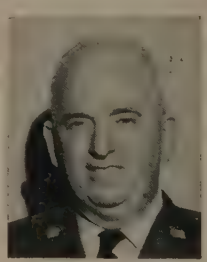


R. SACKMAN

Mr. Sackman had joined Ampex in 1953 to establish and manage the firm's Washington district office. Previously, he headed a Department of Defense research and development branch devoted to recorders and data-processing systems. He attended George Washington University and is a member of Sigma Tau, American Management Association, and the Instrument Society of America.

❖

F. J. Shannon (A'41–SM'52), Special Assistant for Electronics to the Director, Directorate of Maintenance Engineering at Headquarters, Air Materiel Command, retired January 31, 1957, after more than twenty-six years of active and reserve duty.

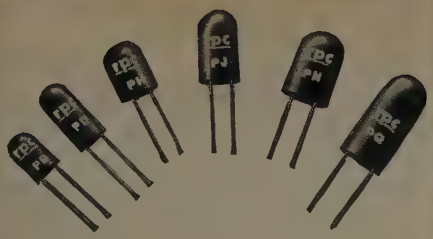


F. J. SHANNON

Colonel Shannon began his life career in radio engineering and electronics with the issuance of an amateur radio license in 1915, followed closely by his becoming a merchant marine radio officer in 1916 and a chief radioman in the U.S. Navy in 1917. He was employed by engineering departments of various broadcasting companies from 1926 to 1942, chiefly WCAU, Philadelphia, Pennsylvania, until his return to military service with a direct commission as a captain in the Air Corps.

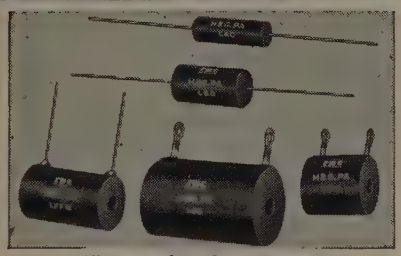
During World War II, the colonel was senior wing electronics officer of a B-29 wing in the Far East. He had been stationed at Headquarters, Air Materiel Command, since January, 1953, and was Assistant for Electronics to the Deputy Commander for Production, with staff surveillance over several electronic projects including the Distant Early Warning Line before assuming the position he is now retired from in July, 1955.

(Continued on page 64A)



NEW **Printed Circuit Precision Resistors**

To meet the requirements for printed circuitry, RPC has developed Type P Encapsulated Wire Wound Precision Resistors Miniature, single ended units designed for easy rapid mounting on printed circuit panels with no support other than the wire leads. Many newly developed techniques are employed in the manufacture of Type P Resistors. These units can be operated in ambient temperatures up to 125°C. and will withstand all applicable tests of MIL-R-93A, Amdt. 3. Available in 6 sizes, rated from 1/10 watt to .4 watt. ¼" diameter by 5/16" long to ⅜" diameter by ¾" long. Resistance values to 3 megohms. Tolerances from 1% to 0.05%.



Encapsulated Precision Wire Wound Resistors

RPC Type L Encapsulated Resistors will withstand temperature and humidity cycling, salt water immersion and extremes of altitude, humidity, corrosion and shock without electrical or mechanical deterioration. Type L resistors are available in many sizes and styles ranging from sub-miniature to standard with lug terminals, axial or radial wire leads. Available for operation at 105° C. or 125° C. ambient temperatures. These resistors will meet all applicable requirements of MIL-R-93A, Amdt. 3. Type L can be furnished with all resistance alloys and resistance tolerances from 1% to .02%.



Wire Wound Precision Resistors

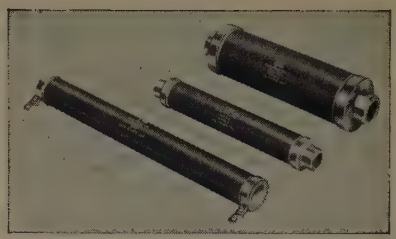
Type A Precision Resistors are widely used for all general requirements. They are available in a wide variety of sizes, styles and terminal types. They can be furnished with all resistance alloys in tolerances from 1% to .02%. Type A will meet the requirements of MIL-R-93A, Amdt. 2, Characteristic B. Special winding techniques, impregnation and thermal aging result in resistors of exceptional stability. Matched resistors, networks and special assemblies can be supplied.

HIGH QUALITY RESISTORS FOR ELECTRONICS

RPC is a widely recognized supplier of high quality resistors to industry, Government Agencies and the Armed Forces. Advanced production methods, modern equipment and scientific skill enables RPC to manufacture resistors of *highest quality* in *large quantities* at *reasonable cost*. Modern manufacturing plant is completely air conditioned and equipped with electronic dust precipitators to insure highest production accuracy. RPC resistors are specified for use in instruments, electronic computers, radiation equipment, aircraft equipment and scientific instruments.

Test equipment and standards for checking and calibrating are equalled by only a few of this country's outstanding laboratories. Our ability to produce resistors of highest quality coupled with prompt delivery have established RPC as a leading manufacturer of resistors. Small or large orders are promptly filled.

Representatives in principal cities. For full information send for latest catalog.



High Frequency Resistors

Used where requirements call for very low inductance, capacitance and skin effect in circuits involving pulses and steep wave fronts. Depending on size and resistance value, these resistors are usable at frequencies to over 400 mc. Resistance values range from 20 ohms to 100 megohms with tolerance of 20% to 5%. 2 types available.

TYPE G resistors (shown) are tubular, in 6 sizes from 4½" long x ¾" diameter to 18½" long x 2" diameter. With band terminals or ferrules. Power rating 10 to 100 watts.

TYPE F resistors (not shown) in 8 sizes from 9/16" long x 0.10" diameter to 6½" long x 9/16" diameter. Lugs or wire leads. Power rating ¼ to 10 watts.



High Voltage Resistors

Type B Resistors are stable compact units for use up to 40 KV. These resistors are used for VT voltmeter multipliers, high resistance voltage dividers, bleeders, high resistance standards and in radiation equipment. They can be furnished in resistance to 100,000 megohms. Available as tapped resistors and matched pairs. Sizes range from a 1 watt resistor 1 inch long x 5/16 inch diameter rated at 3500 volts, to a 10 watt resistor 6½ inches long x 5/16 inch diameter rated at 40 KV. Low temperature and voltage coefficients. Standard resistance tolerance 15%. Tolerances of 10%, 5% and 3% available. Tolerance of 2% available in matched pairs.



High Megohm Resistors

Type H Resistors are used in electrometer circuits, radiation equipment and as high resistance standards. Resistance available to 100 million megohms, (10^{14} ohms). For utmost stability under adverse conditions Type HSD and HSK Hermetically Sealed are recommended. Eight sizes from ⅛ inch to 3 inches long are available. Voltage rating to 15,000 volts. Low temperature and voltage coefficients. Standard resistance tolerance 10%. Tolerance of 5% and 3% available. Also matched pairs 2% tolerance.

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MICRO-MICROAMMETERS

1 MODEL 411 *for maximum stability*

Meets or exceeds the zero stability of the most costly equipment; recommended for long-term control, alarm, and monitoring work, as in thickness gaging and reactor control. No transients created by switching from range to range.

★ RANGES: two per decade, from 10^{-3} to 10^{-11} ampere full scale.

★ ZERO DRIFT: less than 2% per week, with source voltages above 10 volts.

★ TIME CONSTANT: less than 4 seconds on the 10^{-11} range with 5000 mmf across input.



2 MODEL 410 *for maximum sensitivity*

The general purpose instrument for measurement and control of microcurrents. Typical uses: currents in ion gages, ion chambers, photocells, vacuum tube grids, back currents of silicon transistors.

★ RANGES: two per decade, from 10^{-3} to 3×10^{-13} ampere full scale.

★ ZERO DRIFT: less than 2% per day, with source voltages above 300 millivolts.

★ TIME CONSTANT: less than one second on the 10^{-11} range with 5000 mmf across input.

BOTH MODELS include a 250-volt tap for polarizing ion chambers, an output that drives 50-millivolt and 5-milliampere recorders, input and output connections at both front and back. Suited to both bench and rack mounting, and available with a contact meter in place of standard meter.

DESCRIPTIVE LITERATURE is now available. A request on your company letterhead will bring your copy promptly.

KEITHLEY INSTRUMENTS, INC.
12415 Euclid Ave., Cleveland 6, Ohio

IRE People

(Continued from page 62A)

The General Electric Company announced the establishment of an Advanced Semiconductor Laboratory to bridge the gap between basic research and semiconductor product engineering. The new laboratory will take over and expand the activities in semiconductor research previously performed by the Company's Electronics Laboratory.



H. M. SULLIVAN

At the same time, the appointment of **H. M. Sullivan** (SM'55) as manager of the General Electric Advanced Semiconductor Laboratory was announced. He had been former manager of the company's Electronics Laboratory at Syracuse, N. Y. In his new post he will be responsible for the technical and administrative aspects of the Semiconductor Laboratory.

Immediately prior to joining General Electric in 1955, Dr. Sullivan had spent more than ten years directing research in physical and chemical fields.

Born in Mayfield, Kentucky, Dr. Sullivan was graduated from the University of Kentucky in 1931 with a bachelor of science degree in physics. He received his master of science degree in physics and mathematics in 1933. In 1938, Dr. Sullivan was granted a doctorate degree in physics and physical chemistry by Pennsylvania State University.

He is a member of many scientific organizations including the American Physical Society, the American Institute of Physics, American Chemical Society, the Institute of Radio Engineers and the American Institute of Electrical Engineers.

❖

The appointment of **D. E. Bently** (M'56) as Director of Research of Electrical Communications, Inc., San Francisco, Calif. was recently made.

In his new assignment Mr. Bently is in charge of development of transistorized devices for telephone, radio communications and industrial control applications for the thirty-year old firm.



D. E. BENTLY

Prior to his present appointment, Mr. Bently was project engineer for Donner Scientific Company, Berkeley, Calif., where he adapted the Donner servo accelerometer for several special military applications and developed

(Continued on page 66A)

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MICROWAVE PROGRESS

Frequency Measurement Devices

A couple of years back, it seemed to us that there were almost as many frequency measuring devices as frequencies. Anticipating that, sooner or later, some sort of definitive material would be needed, our engineer, Bob Lebowitz, consolidated the scattered, available information into his excellent report, "Frequency Measurement Devices"

This report provides a valuable summary of the various equipment types for measuring frequencies in the 300 to 40,000 mc/s range, and a succinct reference source for their respective design considerations and applications. It covers coaxial and cylindrical cavity wavemeters; crystal oscillator frequency standards; and use of stable reference spectral lines.

Most of the commercial requirements for precision are met by open circuited coaxial and right cylindrical waveguide cavities. Since the $\lambda/4$ and $3/4\,\lambda$ coaxial cavities can be made smaller than right cylindrical waveguide cavities, they are generally preferred for lower microwave frequency measurements. To overcome the critical design problem of contacting the movable plunger without introducing contact resistance in coaxial frequency meters, it has been found more satisfactory to use a non-contacting choke system rather than shorting fingers.

Broadband cavity frequency meters have accuracies that vary between .01 and 1%. For accuracies greater than .001%, low frequency quartz crystal standards are utilized. For microwave applications, multiplying and heterodyning means are required to compare the l.f. frequency oscillator signal with the signal of unknown frequency.

Although we've tried to cover most of the aspects of Bob Lebowitz' report in the preceding paragraphs, space has forced us to omit many of the important details. But, the full report on frequency measurement devices is available to you for the asking. Just request on your company letterhead, "PRD Report Vol. 2 No. 2E".



PRD Precision Heterodyne Frequency Meter

provides direct reading of any frequency from 100 to over 10,000 mc/s to an accuracy of <.03%!

This is the one unit that has all the features required for both laboratory measurements and production and field testing of transmitters and receivers. Completely self-contained and portable, the 504 Precision Heterodyne Frequency Meter gives you quick, simple operation with both CRT and aural presentation, and a new, exclusive direct interpolating dial. Consisting of a spiral scale fitted with an adjustable index, the dial permits direct interpolation to 0.1 mc/s at all settings. *No calibration charts needed* when you use the 504 Heterodyne Frequency Meter.

SPECIFICATIONS
Frequency Range: measures 100 to over 10,000 mc/s; generates 500 to 900 mc/s and harmonics
Calibrator Accuracy: 0.002% at 5 mc/s crystal check points
Interpolation: < 0.03% between 5 mc/s crystal check points
Resettability: < 0.02%
Input Sensitivity: at 500 mc/s and above—30 dbm; at 100 mc/s—5 dbm
Heterodyne Oscillator: 500-900 mc/s
Crystal Calibrator: Built-in 5 and 50 mc/s quartz crystal standards. The 5 mc/s crystal is temperature-controlled.
Power Requirement: 115/230V, 50-60 cps, single phase, 125 watts
Price: $695 f.o.b. Brooklyn, N. Y

For all the important details on PRD Heterodyne Frequency Meter, please request on your company letterhead, "PRD Technical Data Sheet 504E"

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750 VA OUTPUT—360 to 440 CPS



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CML's Model 1450-C is available as a fixed frequency unit employing a tuning fork oscillator to give a frequency accuracy and stability of 1 part in 50,000. This stability is independent of line voltage or frequency.

Specifications for the Model 1450 and 1450-C are available on request.

We custom-build units to your exact specifications. Our design engineering department will be happy to help you with your particular problems at no cost or obligation.

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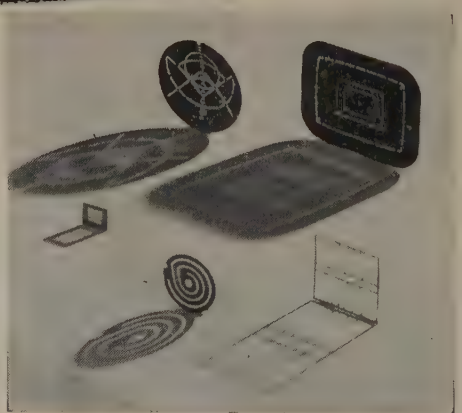
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IRE People

(Continued from page 64A)

a new system for pure delay of information for analog computer applications.

As senior engineer for Electronic Products Corp., Santa Barbara, Calif., he designed servo test equipment for the guided missiles. Mr. Bently was also a research engineer at the Autonetics division of North American Aviation where he worked on servo systems for airborne search and track radar and fire control systems.

Mr. Bently is a member of the American Institute of Electrical Engineers, Tau Beta Pi and Eta Kappa Nu, and an associate member of Sigma Xi.

He received a B.S. degree in electrical engineering with distinction in 1949 and an M.S. degree in 1950, both from the State University of Iowa. Mr. Bently has completed several additional courses at the University of California and is currently attending the graduate college of the same university in preparation for an advanced engineering degree.

In addition to his current duties for Electrical Communications, Inc., Bently maintains his own research and development laboratory.

❖

K. H. Meissner (SM'51) has been named Technical Manager for Europe by the Consolidated Electrodynamics Corporation, Pasadena, Calif. CEC's new office in Zurich, Switzerland opened recently under his direction. It will provide customers and sales representatives with direct company contact.



K. H. MEISSNER

Before joining CEC in 1955, Mr. Meissner was head electronics engineer at Summers Gyroscope in Santa Monica, Calif., since 1951. There he developed an ufh proportional drone control system and several transistor circuits.

Mr. Meissner was also chief engineer at the Stamford Electronics Co. in Connecticut and project engineer with Electro-Impulse Labs at Red Bank, N. J.

Mr. Meissner is a graduate of the Swiss Federal Institute of Technology in Zurich. He worked in the Swiss electronic industry from 1941–1947. In 1948 he came to the United States and obtained his citizenship in 1952. He is a member of ISA and SESA.

❖

Appointment of **A. R. Pearlman** (A'54) as Chief Engineer has just been announced by Universal Atomics Corp. Westbury, L. I., New York.

He will be in charge of all new product development and applications engineering of UAC electronic power supplies, instruments, circuits, and devices.

(Continued on page 68A)

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Tremendous Production Facilities—323,000 sq. ft. plant devoted to variable resistors.

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Dependable Delivery—exceptionally good delivery cycle.

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ONE MEGACYCLE PULSE GENERATOR

SIMPLIFIES YOUR NON-LINEAR CIRCUIT DESIGN

MODEL B-3
PULSE GENERATOR...$1,750.00

- Pulse Widths from .08 to 10,000 μs
- Duty Factor: 25%
- Adjustable Rise Time from .02 to 1 μs
- Positive or Negative pulses
- Repetition Rates through 1 megacycle
- Internal Delay to 10,000 μs

The B-3 series is adaptable for multiple pulse outputs

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"SAL-MET" NON-CORROSIVE FLUX—solders copper to aluminum, aluminum to aluminum; in fact, any metal to any metal is possible when using "SALMET" No special preparation on material to be soldered. Use conventional solder, applied with quick heating, regular soldering iron, torch or pot. Used by aircraft, government agencies and leading industrials. Stocked nationally by electronic distributors. Send for free information and catalog.

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IRE People

(Continued from page 66A)

Mr. Pearlman, a specialist in transistor circuitry and holder of an original patent for transistorized DC power converters, comes to Universal Atomics from Clevite Transistor Products, where he had been Assistant Director for Technical Services.

❖

C. A. Frische (SM'54), former vice-president for operations, was named recently to the post of executive vice-president of Sperry Gyroscope Division of Sperry Rand Corp.



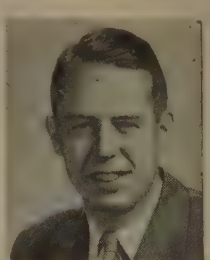
C. A. FRISCHE

Dr. Frische, new executive vice-president, has been head of Sperry headquarters operations since June, 1954, and prior to that vice-president for engineering beginning in 1945. With a varied background in invention and administration since joining the company in 1933 as a research engineer, he has held positions as senior project engineer, research director and chief research director. He was active in such engineering fields as flight instruments, control systems, bombing systems and microwave radar.

A graduate of Miami University, Oxford, Ohio, Dr. Frische did graduate work at the University of Iowa where he received an M.S. degree and a doctorate in physics followed by a research appointment in physics at Columbia for one year. Holder of 23 patents, he is a member of the American Institute of Physics, associate fellow of the Institute of the Aeronautical Sciences, and a member of the American Association for the Advancement of Science and American Ordnance Association.

❖

J. F. Kalbach (SM'51) has recently been appointed field engineering manager for the ElectroData Division of Burroughs Corporation, Pasadena, Calif.



J. F. KALBACH

Mr. Kalbach, who has held several engineering positions with ElectroData, will be responsible for the over-all administration of field engineering activities for the division's three product lines —Datatron high-speed electronic digital computers, E101 desk-size computers, and Series G high-speed printing, tabulating and punch card equipment.

Prior to joining ElectroData in 1955, Mr. Kalbach was manager of engineering

(Continued on page 70A)

Another Hoffman FIRST!

SILICON DIFFUSED JUNCTION FULL-WAVE RECTIFIERS



Replace Vacuum tubes 5R4-GY, 5U4G and others, in most military applications

. . . especially designed to replace, and exceeds the current ratings of full-wave vacuum rectifiers 5R4-GY, 5U4G and others, in critical electronic circuits.

Military applications and equipment (radar, aircraft, missles) will benefit from the following features of HOFFMAN Silicon Diffused Junction Full-Wave Rectifiers:

COMPARISON OF CHARACTERISTICS

	Peak Inverse Plate Voltage	Max. Average Output Current	Note 2	Typical Rectifier Efficiency*
Hoffman HFWR-1	2100 V	400 ma @ 2100V (Note 1)	430 V 220 ma	98.3%
5R4-GY	2100 V	250 ma	400 V 200 ma	79.5%
5U4-G	1550 V	270 ma	400 V 200 ma	75.5%

Note 1—At 2100 V peak inverse plate voltage, 25°C ambient, with choke input to filter. Max. Avg. output current of 300 ma at 2100 V peak inverse with 12 mfd max. capacitor input to filter.

Note 2—DC output voltage and current when indicated type is substituted in a typical rectifier circuit with choke input to filter.

* Operated at 1414PIV into a 1650 ohm Load.

★ *High efficiency (see chart)*
★ *Long life*
★ *Maximum reliability*
★ *Long time stability*
★ *No energy loss in a hot filament*
★ *Small size—for compact design needs*
★ *No maintenance required in critical military circuits*

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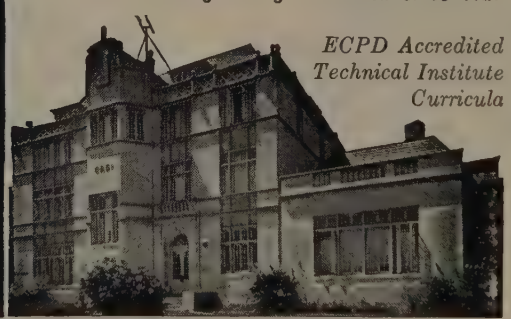
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FOR SIMULTANEOUS OBSERVATION OF TWO SEPARATE SIGNALS ON A SINGLE BEAM OSCILLOSCOPE



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- Wide Range of Input Signals from 10 MV to 200 V RMS
- Wide Range of Frequency Response with Useful Amplication



VANGUARD INSTRUMENT CORPORATION
184 CASPER STREET, VALLEY STREAM, N.Y.

IRE People

(Continued from page 68A)

for William Miller Instrument Company since 1951. From 1947 to 1951 he served as a staff member of the University of California Scientific Laboratory, Los Alamos, and for ten years preceding this, was with General Electric Company.

A magna cum laude graduate from the University of Washington in electrical engineering and a member of Tau Beta Pi, Sigma Xi and Zeta Mu Tau, Mr. Kalbach is also a registered professional engineer in California, New Mexico and Massachusetts. He is a member of the American Institute of Electrical Engineers.

❖

Electro-Pulse, Inc., Culver City, Calif., announces the appointment of **N. H. Enenstein** (S'46–A'49–M'55) as Vice-President and Director of Engineering. Dr. Enenstein will direct the increased research, development, and product engineering activities in electronic instrumentation at Electro-Pulse.



N. H. ENENSTEIN

Prior to his new position, Dr. Enenstein was engaged for a period of over seven years in the design and development of microwave antennae, radar systems, transistor circuits, and data processing systems design at Hughes Aircraft Company. His most recent position at Hughes was as project head for a military data processing system.

Dr. Enenstein received his A.B. degree in 1946 from UCLA, and his M.S. and Ph.D. degrees in electrical engineering and physics from the California Institute of Technology in 1947 and 1949, respectively.

❖

D. H. Ewing (SM'46–F'54), Vice-President, RCA Laboratories, has been named Vice-President, Research and Engineering, of the Radio Corporation of America, it has been recently announced.

The new appointment was one of several announced in RCA's research and engineering organizations. The others included: **James Hillier** (SM'55–F'57), who has been Chief Engineer, RCA Commercial Electronic Products, appointed General Manager, RCA Laboratories; **G. H. Brown** (A'30–F'41), who has been Director of the Systems Research Laboratory, RCA Laboratories, appointed Chief Engineer, RCA Commercial Electronic Products; and **H. W. Leverenz** (SM'54–F'56), who has been Director of the Physical and Chemical Research Laboratory, RCA Laboratories, appointed Assistant Director of Research, RCA Laboratories.

(Continued on page 72A)

AN EXPOSITION OF

Armed Forces Communications and Electronics

EVENT: **AFCEA Annual National Convention**
Armed Forces Communications & Electronics Association

TIME: **May 20, 21, 22, 1957.**
Monday, Tuesday, Wednesday.

PLACE: **Washington, D. C.** Sheraton-Park Hotel—All under one roof.

ATTENDANCE: **Expected 3,500 Military & Business.**
Boston Attendance in 1956 was 1,392.

EXHIBITS: **155 Units. American Manufacturers of Communications and Electronics Equipment for Military Use.**

This Program means business:

Monday, May 20th

8:30 AM—Sheraton Hall
Opening Breakfast
9:30 AM— **Official Opening of Exhibits**
10:00 AM—Caribar Room
Chapter Presidents Conference
10:00 AM-12:00 M—Sheraton Hall
Engineering Papers on Research and Application
12:30 PM—Sheraton Hall
Keynote Luncheon
1:00 PM-5:00 PM—Adams Hamilton Room
Industrial Movies
2:30 PM-4:30 PM—Sheraton Hall
Monitored Panel on Scatter Propagation
7:00 PM—Sheraton Hall
Buffet Supper

Exhibits: 9:30 AM—9:00 PM

Tuesday, May 21st

9:00 AM—Caribar Room
Council & Directors Meeting
10:00 AM-12:00 M—Sheraton Hall
Engineering Papers on Research and Application
12:00 M—Box Lunch
Tour—Naval Research Laboratory
1:00 PM-5:00 PM—Adams Hamilton Room
Industrial Movies
6:00 PM—Continental Room
Reception
7:30 PM—Sheraton Hall
Banquet

Exhibits: 9 AM—9 PM

Wednesday, May 22nd

8:00 AM—Caribar Room
Officers & Directors Breakfast
10:00 AM-12:00 M—Sheraton Hall
Engineering Papers on Research and Application
12:30 PM—Sheraton Hall
Industrial Luncheon
1:00 PM-5:00 PM—Adams Hamilton Room
Industrial Movies
2:30 PM-4:30 PM—Sheraton Hall
Procurement Management Forum

Exhibits: 9 AM—5 PM

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IRE People

(Continued from page 70A)

Dr. Ewing will be responsible in his new position for RCA Laboratories and RCA's Engineering Services. All of the new appointees, with the exception of Dr. Brown, will make their headquarters at the David Sarnoff Research Center, Princeton, N. J. Dr. Brown will have his office in Camden, N. J.

Dr. Ewing has been the head of RCA Laboratories since November, 1955. Born in 1915 in Mitchell, Ind., he was graduated from Butler University, Indianapolis, and received his Ph.D. degree in physics from the University of Rochester in 1939. Following two years of teaching at Smith College, and wartime association with the Radiation Laboratory, Massachusetts Institute of Technology, Dr. Ewing joined RCA in 1945 as Manager of the Teleran Engineering Section of the RCA Victor Division. From 1949 to 1951, he was granted a leave of absence from the company to serve on the Air Navigation Development Board in Washington. Returning in 1951, he became Director of Research Services of the RCA Laboratories in Princeton, N. J. Subsequently he served as Director of the Physical and Chemical Research Laboratory and as Administrative Director, RCA Laboratories, until his appointment as Vice-President, RCA Laboratories, in 1955. He holds the honorary degree of Doctor of Science, awarded by Butler University in June, 1955.

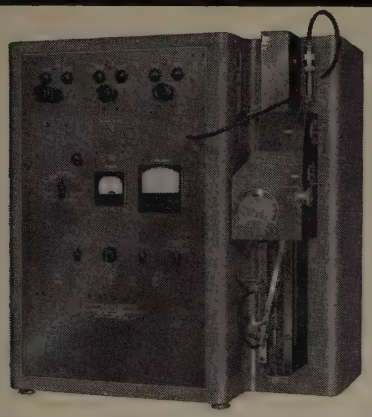
Dr. Hillier, a pioneer in the development of the electron microscope, has been associated with RCA since 1940 as a research physicist and engineer. Born in Brantford, Ontario, in 1915, he studied at the University of Toronto, where he received the degrees of B.A. in mathematics and physics in 1937, M.A. in physics in 1938, and Ph.D. in physics in 1941. In 1939 and 1940, Dr. Hillier was associated as a research assistant at the Banting Institute of the University of Toronto Medical School, where he and his associates built the first successful high resolving power electron microscope in the western hemisphere. Joining RCA Laboratories as a research physicist in 1940, Dr. Hillier designed the first commercial electron microscope to be made available in the United States, and subsequently made many basic contributions to improved design and applications of the instrument. In 1953, he became Director of the Research Department of Melpar, Inc., returning to RCA in late 1954 to become Administrative Engineer in charge of Research and Engineering. He was named Chief Engineer in charge of RCA Commercial Electronic Products, in November, 1955.

Dr. Brown, who joined RCA in 1933 as a research engineer, has made major contributions to radio and television broadcast communications, particularly in the fields of antenna design and ultra-high frequency transmission. Born in 1908 in North Milwaukee, Wis., he studied at

(Continued on page 74A)

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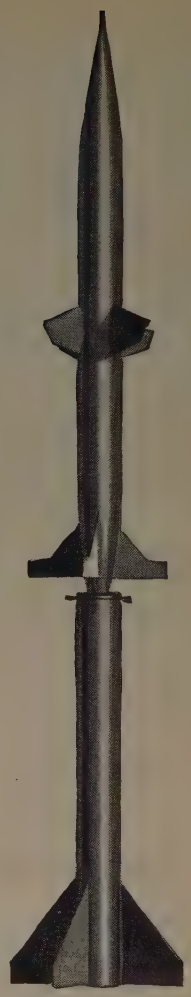
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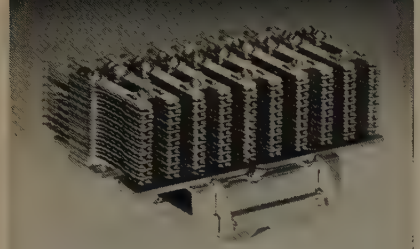
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IRE People

(Continued from page 72A)

the University of Wisconsin, where he received the degrees of B.S. in 1930, M.S. in electrical engineering in 1931, Ph.D. in 1933, and the E.E. professional degree in 1942. After two years as Regent Fellow at the University of Wisconsin, Dr. Brown became a research engineer with the RCA Manufacturing Company in Camden, N. J., where he developed the turnstile and other antennas used in television transmission. During 1937 and 1938, he worked as a consulting radio engineer in Montclair, N. J., returning to RCA in 1938. In 1942, he was transferred to RCA Laboratories, where he undertook wartime research and development of radio and radar antennas, as well as various applications of radio frequency heating. He was appointed Director of the Systems Research Laboratory, RCA Laboratories, in 1951.

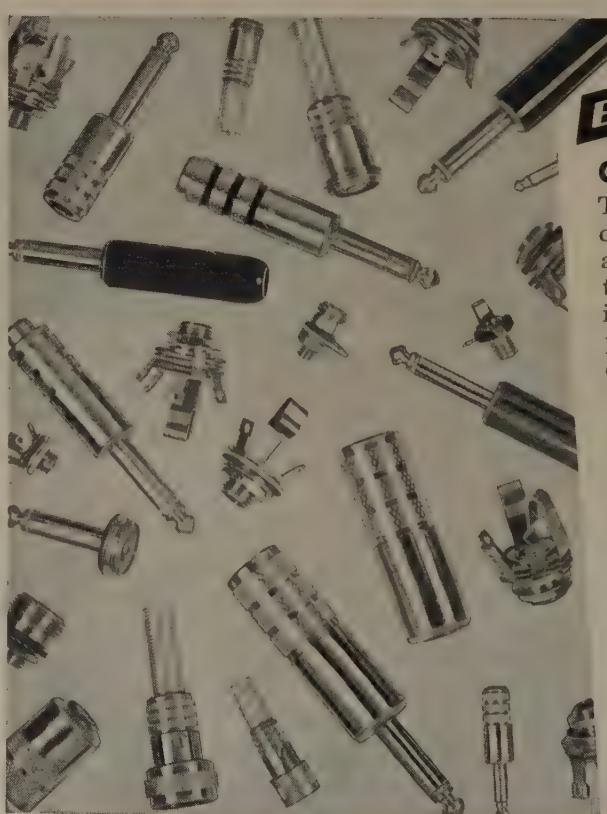
Mr. Leverenz, who will assist Dr. Irving Wolff, Vice-President, Research, of RCA, is a pioneer in the development of phosphors used in television and fluorescent lighting. He has been associated with RCA since 1931, when he joined the company as a chemico-physicist. Born in Chicago in 1909, Mr. Leverenz was graduated from Stanford University in 1930 and studied physics and chemistry at the University of Munster as an exchange fellow of the Institute of International Education. From 1931 to 1938, he was a member of RCA's Electronic Research Group in Camden, N. J., participating in the development of electronic television into a practical system. During this period, he pioneered in devising superior phosphors and in evolving methods for synthesizing and testing them. During World War II, he was responsible for the development of various phosphors essential in radar display. Since 1942, he has been in charge of research on electronically active solids at RCA Laboratories, and became Director of the Physical and Chemical Research Laboratory in June, 1954.

❖

"Feedback Controls, Inc., of Waltham, Mass., manufacturers of components and systems for control and computation, announces the appointment of **T. P. Heuchling** (SM'56) as Engineering Vice-President.

Mr. Heuchling, who will supervise engineering for the company, received his S.B. and S.M. degrees in electrical engineering at M.I.T. He was a member of the staff at the M.I.T. Servomechanisms Laboratory for five years, and served at Ultrasonic Corporation for four years, before joining Feedback Controls as chief engineer.

(Continued on page 76A)



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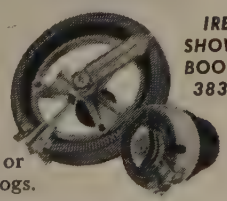
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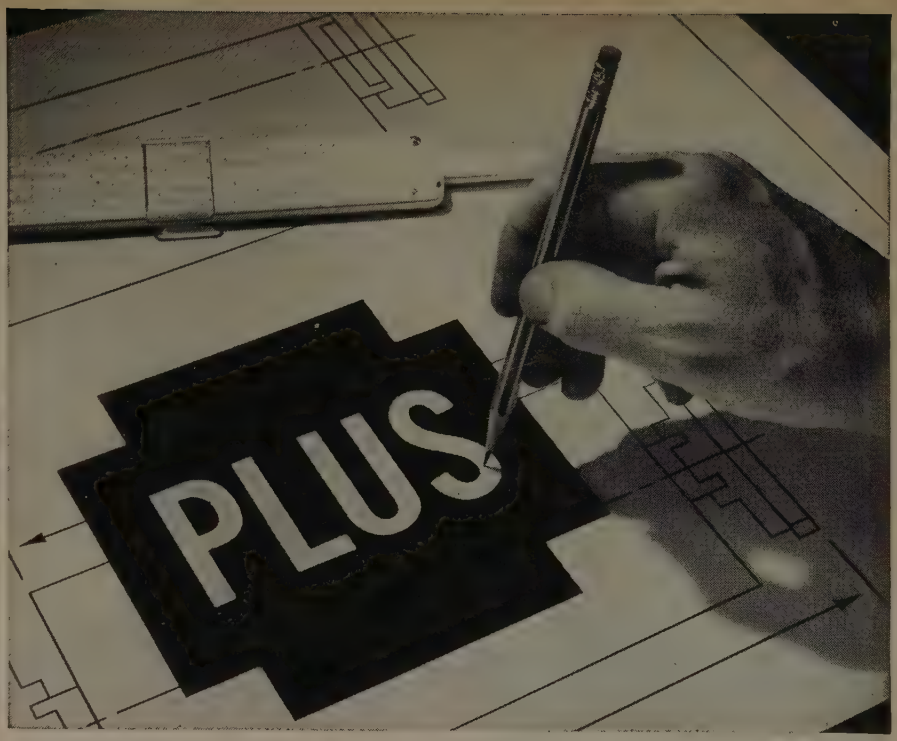
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IRE People

(Continued from page 74A)

W. E. Stewart (A'35–SM'46) has been named assistant to the vice-president of engineering and research at the Standard Register Company, Dayton, Ohio.



W. E. Stewart

Before coming to Standard Register, Mr. Stewart was director of engineering at Maico, Inc., Minneapolis, Minn. His previous business associations include the Victor Division of the Radio Corporation of America, the Civil Aeronautics Authority, and an Iowan radio station. He was also a member of the United States Signal Corps. He received his bachelor's and master's degrees in science from the University of Nebraska, and he holds a fellow membership in the Audio Engineering Society.

❖

L. M. Biberman (M'49–SM'55) has been appointed by the University of Chicago to the position of Director of the Electronics Division of Chicago Midway Laboratories.

Since 1944 Mr. Biberman has been a member of the Technical Staff of the Naval Ordnance Test Station, China Lake, Calif., where he was responsible for the design of the NOTS Aeroballistics Laboratory and for the early SIDEWINDER seeker design. His most recent work included missile vulnerabilities and countermeasures studies.

At Chicago Midway Laboratories Mr. Biberman will be concerned with infrared, optical, and electronics projects.

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Professional Group Meetings

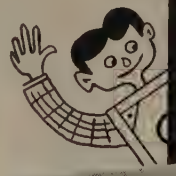
AERONAUTICAL & NAVIGATIONAL ELECTRONICS

Dayton—December 6

"Transistors in Airborne Equipment," H. J. Woll, Circuit Development, Defense Electronic Products, RCA.

(Continued on page 79A)

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Professional Group Meetings

(Continued from page 76A)

Antennas & Propagation

Washington—December 11

"Impressions of Poland from the CCIR Warsaw Conference," E. W. Allen and H. E. Dinger.

Washington—November 15

"Communication and Navigation in Rocket Flight Beyond the Atmosphere," L. N. Ridenour, Lockheed Missile System Div.

Audio

Boston—December 13

"Acoustical Design of Music Studios," L. L. Beranek, Bolt Beranek and Newman Inc.

Dayton—December 6

"Present Day Practices in Loudspeaker Design," Louis Hoodwin, Electro-Voice, Inc.

Automatic Control

Boston—February 13

"Economics of Automatic Control: A Case Study," T. V. Atwater, Jr., M.I.T.

Boston—March 12

"Some Recent Developments with Pneumatic Controls," J. L. Shearer, M.I.T.; "Patent Problems and Techniques" by R. H. Rines, Rines and Rines.

Boston—May 7

"The Dynamics of Manufacturing Processes," D. P. Campbell, M.I.T.

Communications Systems

Syracuse—October 24

"Fundamentals of Information Theory Applied to Communications," J. P. Costos, General Electric Company.

Syracuse—November 28

"The Use of Ferrites in Microwave Systems," Tore Anderson, Airtron, Inc.,

Component Parts

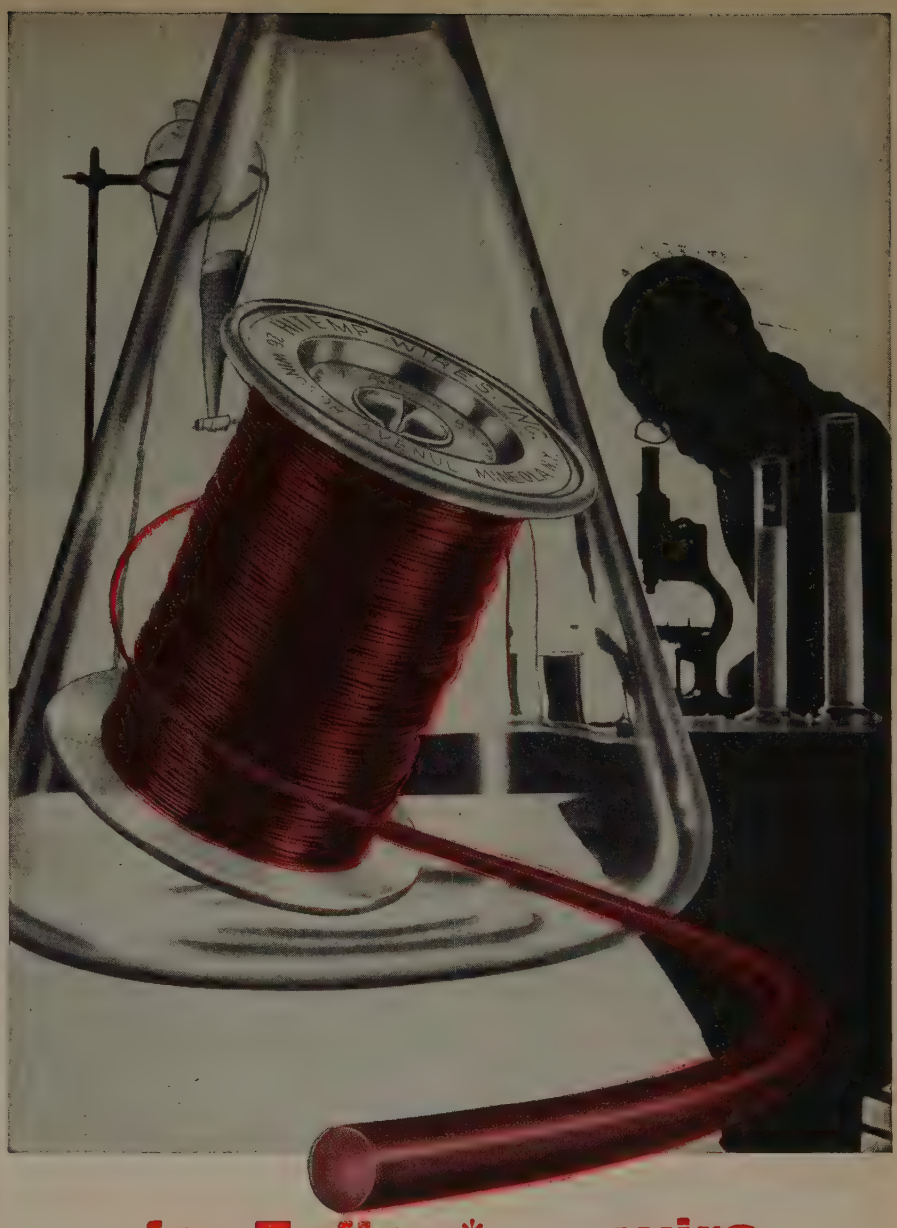
Washington—November 14

"High-Speed RF Switches," H. D. Quigley, Melpar, Incorporated.

Washington—December 12

"Polymers as Dielectrics," John Hoffman, National Bureau of Standards.

(Continued on page 80A)



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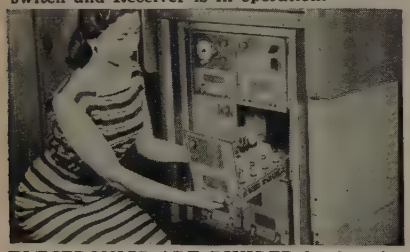
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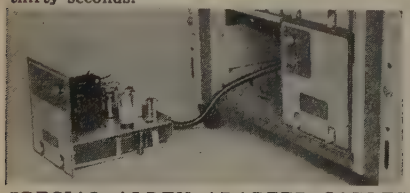
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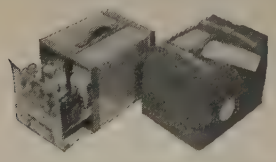
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Professional Group Meetings

(Continued from page 79A)

Electron Devices

Boston—December 11

"Selected Topics of Recent Microwave Tube Research and Development," R. Kompner, Bell Telephone Laboratories.

San Francisco—November 21

"A Flat Picture Tube," W. R. Aiken, Kaiser Aircraft & Electronics.

Electronic Computers

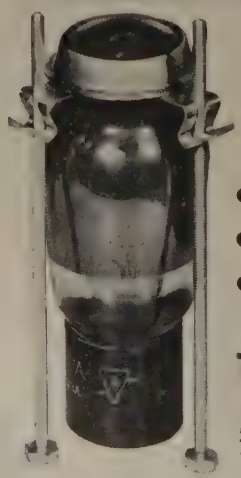
Baltimore—December 12

"Characteristics of Ferrite and Metal Cores and Their Application to Computer Memories," D. R. Erb, Westinghouse, Friendship Airport, Baltimore, Maryland; "Digital Simulation of an Airborne Fire Control Computer," F. J. Piper, Westinghouse, Air Arm Division, Baltimore, Maryland.

Dayton—December 6

"A Survey of Electronic Computers—Analog & Digital," R. T. Harnett, Aeronautical Research Laboratory, Wright Air Development Center; "A Survey of Electronic Computers—Analog & Digital," W. Keating, NCR, Dayton.

(Continued on page 82A)



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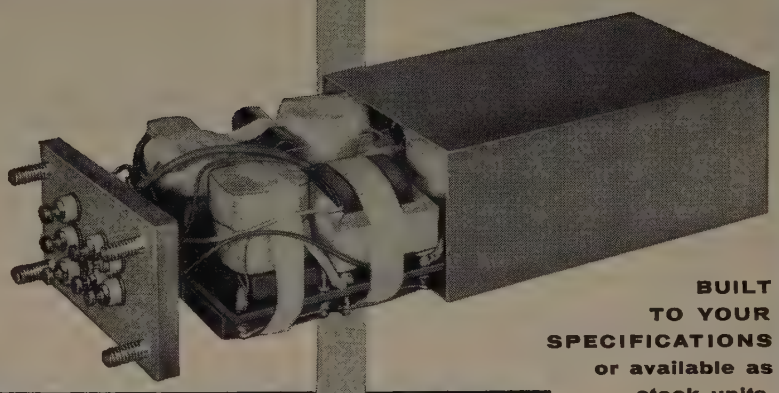


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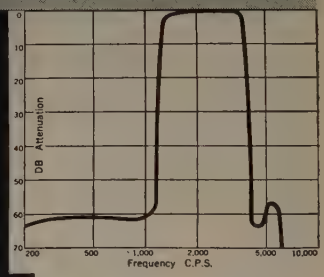
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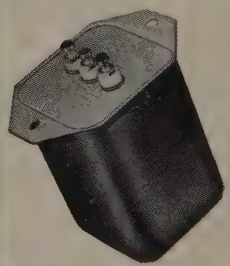
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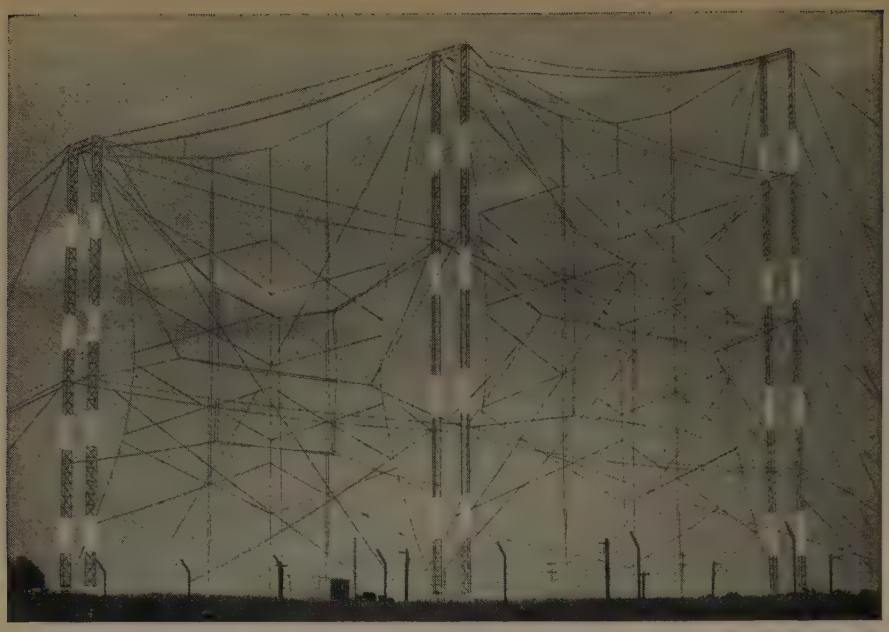
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Professional Group Meetings

(Continued from page 80A)

Detroit—December 19

"The SAGE System of Air Defense," Benjamin Gurley, Lincoln Laboratory, M.I.T.

Detroit—November 28

"Solid State Computers," J. Chuan Chu, Remington Rand Univac.

New York—December 13

"Analog to Digital Conversion Methods," R. C. Whittle, Federal Telecommunications Laboratory.

New York—November 15

"The IBM RAMAC System-Memory Unit Operation," D. A. Shoultes, IBM Corp.; "The IBM RAMAC System—Inquiry Station," H. A. Reitfort, IBM Corp.

Philadelphia—November 20

"The Application of Solid State Devices to Digital Computers," J. A. Rajchman (speaker) and A. W. Lo (co-author), RCA Laboratories.

Philadelphia—December 18

"Symbolic Design Techniques," I. S. Reed, Lincoln Laboratory, M.I.T.

San Francisco—December 11

"Design Consideration for Computer Tape Transports," Bob Brumbaugh, Ampex Corporation.

Engineering Management

Los Angeles—December 18

"Can Engineers Justify Their Salaries?" Burgess Dempster, Electronic Engineering Co. of Calif.; "The Engineering Budget," Harley Iams, Hughes Aircraft Company.

Philadelphia—November 15

"Group Discussion of a Live Engineering Management Problem," Capt. Grayson Merrill, Bureau of Ordnance, Washington, D. C.

Rome-Utica—November 27

"Decentralization—The Key to Engineering Management," O. P. Haywood, Jr., Sylvania Electric Products, Inc.

Information Theory

Albuquerque—Los Alamos—December 13

"Some Considerations Concerning the Problem of Library Automation," Gene Bussey, Sandia Corporation.

(Continued on page 85A)

Professional Group Meetings

(Continued from page 82A)

Medical Electronics

Buffalo—Niagara—January 8

"The Nerve Impulse—Electronics and Electro-Ionics," W. J. Adelman, Jr., University of Buffalo.

San Francisco—December 6

"Advances in X-ray Microscopy," Howard Patte, X-Ray Research Laboratory, Stanford University.

Microwave Theory & Techniques

Boston—December 13

"Elementary but Unsolved Problems in Microwave Filter Design," E. G. Fubini, Airborne Instruments Laboratory.

New York—December 6

"Network Formulation of Microwave Problems," Nathan Marcuvitz, Brooklyn Polytechnic Institute.

San Francisco—December 5

"Research Program of the Stanford Microwave Laboratory," E. L. Ginzton, Stanford University.

Military Electronics

Boston—December 3

"Voice Transmissions by Ionospheric Scatter," Rolf Wundt, USAF Cambridge Research Center.

Los Angeles—November 27

"The Future of Mobile Power Plants," Peter Kyropoulis, California Institute of Technology; "ASTIA Services," George Tsujimoto, ASTIA—Western Regional Office.

Nuclear Science

Pittsburgh—September 21

Tour of Westinghouse Atomic Power Plant. Demonstrations and lectures were presented on the work on such varied topics as inertial gyros, low temperature superconductivity, insulation developments and testing, lubrication, digital computers, high temperature metallurgy, and electron amplification. The climax to the tour was a demonstration of the first room in the world to be lighted by electroluminescence.

Pittsburgh—November 26

"Nuclear Reactor Control Philosophies," M. A. Schultz, Westinghouse Commercial Atomic Power.

Washington—January 7

"Power Reactor Development in the United States," Clark Goodman, U.S., A.E.C., Washington, D. C.

(Continued on page 87A)



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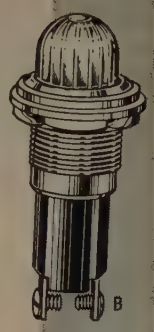

A

Your product benefits 3 ways from the use of a DIALCO Pilot Light:

Enhanced appearance: The glow of light and sparkle of a lens add colorful visual attraction.

Greater safety: A timely warning flashed by a pilot light can prevent damage to equipment.

Added service: Discs inserted behind lenses can be used to deliver specific messages, such as "FUEL LOW", "ON", "OFF", etc.

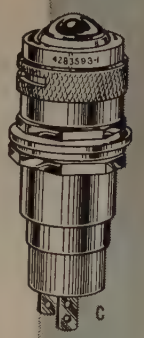

B

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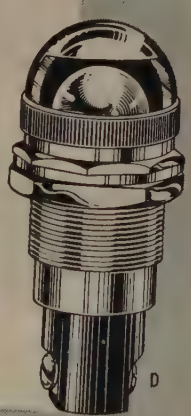
Every assembly is available complete with lamp.

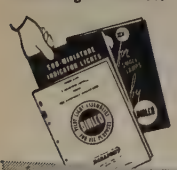
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C

Illustrations are approx. 70% actual size . . . *(A)* No. 8-1930-111 sub-miniature pilot light . . . *(B)* No. 521308-991, with multivue cap . . . *(C)* No. 922210-111, dimmer type . . . *(D)* No. 47901 with light shield cap.

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D



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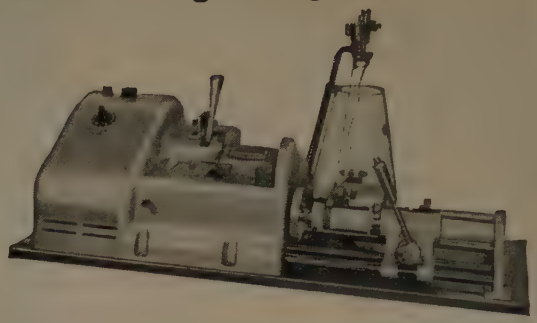


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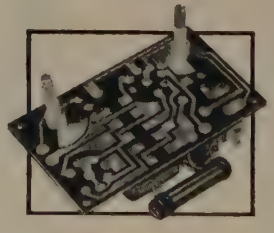
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Professional Group Meetings

(Continued from page 85A)

Production Techniques

Metropolitan New York—December 12

"Automatic Assembly Techniques," Carl Dinglestedt, Sperry Gyroscope Corporation; "Materials Handling," Marshall Sangster, American Plastics Corporation.

San Francisco—November 27

"Production of Ceramic Type Vacuum Tubes," John Soderstrom, Eitel-McCullough Company.

Reliability & Quality Control

Los Angeles—December 17

"Proper Application of Component Parts, the Key to Reliability Improvement," K. F. McCready, Northrop Aircraft, Inc.

Telemetry & Remote Control

Los Angeles—November 20

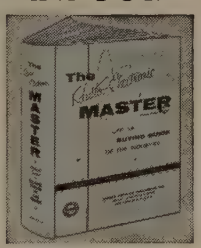
"Transistorized DC Transformers," B. J. McComb, Engineering Magnetics Division of Gulton Industries; "Progress Report—Project Monitor," Tullio Ronzoni, Rheem Manufacturing Co.

(Continued on page 88A)

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*ERIE BUTTON Capacitors are made under U.S. Patent 2,348,693



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Industrial Engineering Notes*

Census Report

About 76 per cent of American households have TV sets, the Census Bureau found in an August, 1956 survey. This compared with 73 per cent in a similar survey the preceding Feburary and 67 per cent in June, 1955. The 1950 Census of Housing reported that only 12 per cent of households had television receivers. Greatest TV growth was in the areas outside the metropolitan areas, which already had high saturation, the survey showed. About 60 per cent of rural households were found to have TV in August 1956, up from 55 per cent in February. Metropolitan figures in the same period gained only from 82 to 84 per cent, from the 78 per cent recorded in June, 1955, the Bureau said. By geographic region, the South as in previous surveys, had the lowest proportion of TV households—65 per cent. The Northeast remained the highest with 85 per cent, and the North Central was next with 79 per cent. In the West, about 75 per cent of all households had TV sets, the survey showed. More detailed statistics will be presented in a report to be issued within a short time, the Census Bureau said.

FCC Actions

The Commission, on request by RETMA, postponed for six months the requirements in Section 15.68 (b) of the rules which provides that the radiation interference limits above 260 mc and the certification requirements with respect thereto shall be met by all new models of uhf television receiver chassis placed in production after December 31, 1956, and by all uhf television receivers manufactured after June 30, 1957. The present dates are June 30, 1957 and December 31, 1957, respectively. . . .**The Commission invited comments by Feb. 28 to a proposed rule to amend Sect. 9.611 governing the Aviation Services by reducing the present 200 kc frequency separation in the vhf flight test band to 100 kc and 50 kc channel spacing.** Aeronautical Flight Test Radio Coordinating Council requested the change in order to make additional channels available and thus alleviate the heavy loading of the three existing vhf flight test frequencies which is causing undue hazard to safety and property in some areas, the Commission said. . . . **The Commission, on petition by RETMA, amended Part 2 of its rules to change the date from Dec. 1, 1956 to June 1, 1957, for requirement of field intensity measurements of spurious radiations to be submitted with requests for type acceptance of transmitters.** At the same time, and on its own motion, the FCC also postponed for six months the requirement for measuring the power line interference voltage produced by television broadcast receivers on frequencies between 3 and 25 mc. . . . **The Technical Research Division of the Office of the Chief Engineer recently released a report describing the derivation of propagation curves and basic service calculation techniques which were used in computing the tables of Appendix "A" (now rescinded) of report and order released June 25, 1956, in the general TV proceedings in Docket 11532.** The technical information contained in the report—T.R.R. 2.4.16—may be of special interest to TV engineers, the Commission said. A copy of the report may be obtained from the Technical Research Division, Room 7506, New Post Office Building, Washington 25, D.C., upon individual request.

Federal Personnel

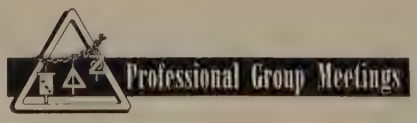
The Federal Communications Commission has announced the appointment of K. W. Miller, now Engineering Assistant to Commissioner R. T. Bartley, to be U. S. Supervisor of CONELRAD, Effective Feb. 15. Mr. Miller will succeed R. J. Renton, whose promotion to Assistant Chief Engineer was announced Nov. 29, 1956 by the FCC.

Frequency Allocations

A statement of operating policies and procedures for the Television Allocations

(Continued on page 92A)

* The data on which these NOTES are based were selected by permission from *Industry Reports*, issues of December 24, and January 7, 14 and 21, published by the Radio-Electronics-Television Manufacturers Association whose helpfulness is gratefully acknowledged.



(Continued from page 87A)

Philadelphia—November 14

"Airborne Telementry," I. P. Magasiny, Tele-Dynamics, Inc.; "Telemetering in the Electric Power Industry," W. E. Phillips, Leeds and Northrup Company.

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6 Transactions, 8 Newsletters. *1, *2-3. EM-3, No. 1-2-3.

Industrial Electronics

Annual publications fee: $2.

Electronics pertaining to control, treatment and measurement, specifically, in industrial processes.

Mr. Carl E. Smith, Chairman, Carl E. Smith Consulting Engineers, 4900 Euclid Ave., Cleveland 3, Ohio.

3 Transactions, *PGIE-1-2-3.

Information Theory

Annual publications fee: $2.

Information theory and its application in radio circuitry and systems.

Dr. M. J. Di Toro, Chairman, Polytechnic Inst. of Brooklyn, Brooklyn, N.Y.

11 Transactions, 1 Newsletter. *2, *3, 4. IT-1, No. 1-2-3. IT-2, No. 1-4.

Instrumentation

Annual publications fee: $1.

Measurements and instrumentation utilizing electronic techniques.

Mr. F. G. Marble, Chairman, Boonton Radio Corp., Intervale Road, Boonton, N.J.

5 Transactions. *2, *3, 4, 5.

Medical Electronics

Annual publications fee: $2.

The application of electronics engineering to the problems of the medical profession.

Dr. Vladimir K. Zworykin, Chairman, RCA Laboratories, Princeton, N.J.

6 Transactions, 1-6 Newsletters, *1.

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Mr. H. F. Engelmann, Chairman, Federal Telecom Labs, Nutley, N.J.

16 Transactions. *Vol. MTT-1, No. 2; *Vol. MTT-2, Nos. 1-3; MTT-3, No. 1-6; MTT-4, No. 1-2-3-4; MTT-5, No. 1.

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Capt. Christian L. Engleman, Chairman, 2480 16th St., N.W., Washington 9, D.C.

Nuclear Science

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Application of electronic techniques and devices to the nuclear field.

Dr. W. E. Shoupp, Chairman, Westinghouse Elec. Corp., Atomic Power Div., Pittsburgh 30, Pa.

6 Transactions, 3 Newsletters. NS-1, No. 1; NS-2, No. 1; NS-3, No. 1-4.

Production Techniques

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1 Transaction. No. 1.

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Dr. Victor Wouk, Chairman, Beta Electric Corp., 333 E. 103rd St., New York 29, N.Y.

9 Transactions, 1 Newsletter, *1, *2, *3, 4-5-6-7-8-9.

Telemetry and Remote Control

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Mr. Conrad H. Hoeppner, Chairman, Radiation, Inc., Melbourne, Fla.

6 Transactions, Newsletter. 1-2. TRC-1, No. 1-2-3; TRC-2, No. 1.

Ultrasonics Engineering

Annual publications fee: $2.

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Dr. J. F. Herrick, Chairman, Mayo Clinic, Rochester, Minn.

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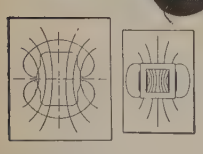
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Industrial Engineering Notes

(Continued from page 88A)

Study Organization (TASO) was finalized and adopted by the TASO Board of Directors at its last meeting. In addition, the TASO Board discussed the selection of panel chairmen, vice-chairman, and panel members using a list of names prepared by G. R. Town, executive director. Agreement was reached and Dr. Town announced he will proceed to solicit the individuals selected for the following five panels: transmitting equipment, receiving equipment, field tests, propagation data, and analysis and theory. Names of these individuals will be announced shortly. The TASO organizational structure consists of the executive director and a board of directors, made up of two representatives of each of the five sponsoring organizations: NARTB, RETMA, Joint Council on Educational Television, Committee for Competitive Television, and the Association of Maximum Service Telecasters, Inc.

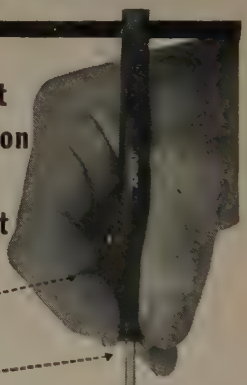
Labor

The demand for engineers and scientists in electronics as well as in government is beyond the supply and the two may not be balanced before 1970, a Labor Department spokesman said recently. Mrs. A. J.

(Continued on page 94A)

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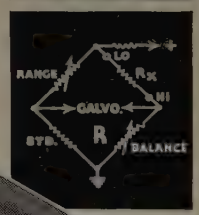
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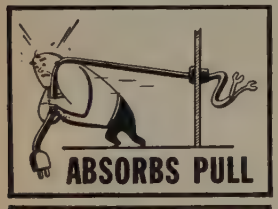
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Industrial Engineering Notes

(Continued from page 92A)

Wickens, Deputy Assistant Secretary of Labor for Employment and Manpower, and Dr. H. L. Bevis, Chairman of the President's Committee for the Development of Scientists and Engineers discussed the present situation and future outlook at a scheduled news conference. Mrs. Wickens said that the demand for engineers and scientists is already rising faster than the supply and all indications are that demand will grow very rapidly in the next five years. Increases in spending both by government and industry for research and development has created much of this demand, she told reporters. Not until 1970, when the number of 18 to 21 year olds eligible for college enrollment increases by about 4.5 million over the 1960 level, will there be a potentially great supply of engineers and scientists, she estimated. Dr. Bevis felt that one solution to the immediate problem would be better utilization of engineers. He said there was evidence that engineers were being wasted on jobs where less fully trained personnel could be used.

Marketing Date Activities

The Census Bureau, Commerce Department, has issued an advance report covering the 1954 Census of Manufactures in the communication equipment and related products field, including radios, electronic tubes, television apparatus, phonographs and phonograph records. The report is Series Number MC-36-3, available from the Census Bureau, Washington, 25, D. C., and all Commerce Department Field Offices, at 10 cents each.

Research

A bibliography of material published between 1921 and July, 1956 on the single-sideband method of transmission in communication systems has been compiled by the Navy and released for industry use through Office of Technical Services, Department of Commerce. The volume, "Single-Sidebands in Communications Systems, a Bibliography," contains 492 references to unclassified books, articles, and research reports on the method. The report, Number PB 111837, may be ordered from OTS, Commerce Department, Washington 25, D. C., at $2.75 each.

RETMA Activities

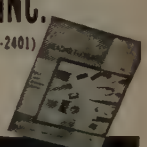
RETMA representatives to serve on the various State Department committees which will prepare the U. S. position to be presented during the 1959 International Radio Conference were announced recently by President W. R. G. Baker who will serve on the Executive Committee. Industry participation in the work of the various committees has been requested by F. C. de Wolf, Chief of the State Department's Telecommunications Division. In addition to Dr. Baker, other RETMA representatives will be: Committee II—Organizational Regulations, J. B. Coleman

(Continued on page 96A)

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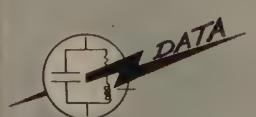


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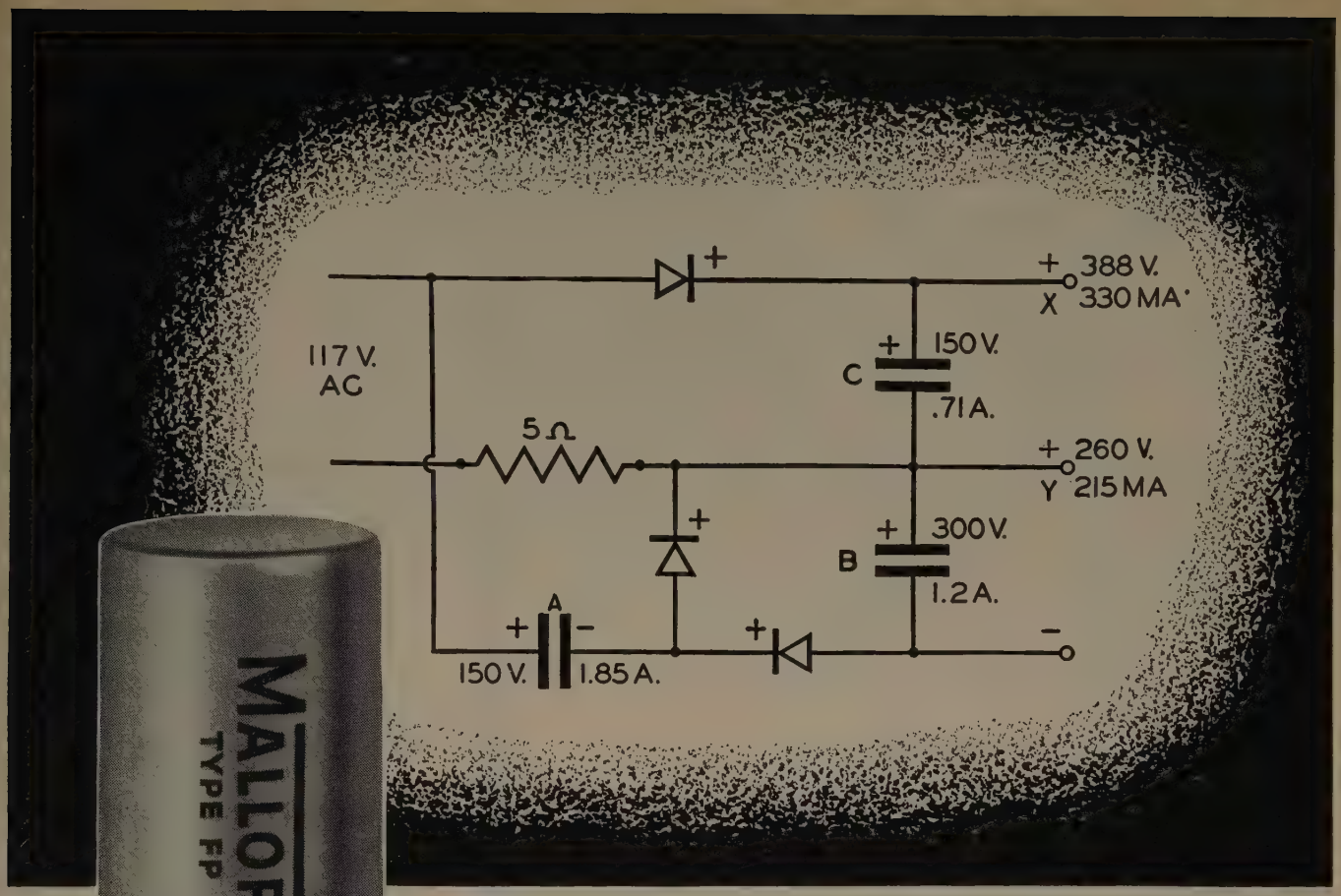


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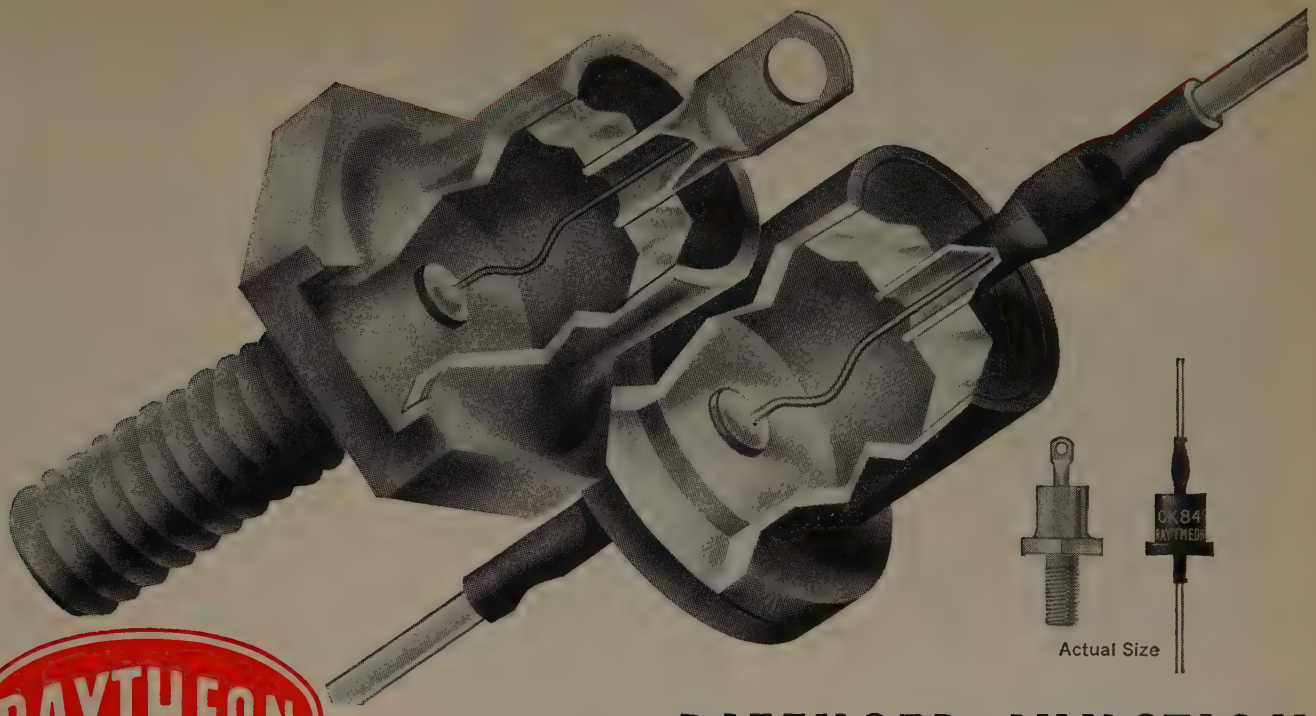
Industrial Engineering Notes

(Continued from page 94A)

of the Radio Corp. of America; Committee III—Allocation of Frequencies and All Proposals Concerning the Frequency List, W. J. Morlock, General Electric Co.; Committee IV—Technical Questions, D.G. Fink, Philco Corp., and Committee V—Operating Regulations, K. V. Curtis, Raytheon Manufacturing Co. A number of individual company representatives also will work with the State Department committees. . . . **The following seven RETMA standards were approved recently by the American Standards Association, according to the RETMA Engineering Department.** Nomenclature and Dimensions for Panel Mounting Racks, Panels and Associated Equipment (RETMA SE-102), C83.9; Requirements for Rectangular Waveguides (RETMA TR-108-A), C83.10; Requirements for Metal Encased Fixed Paper Dielectric Capacitors for D.C. Application (RETMA TR-113-A), C83.11; Requirements for Cable Connectors for Audio Facilities for Radio Broadcasting (RETMA TR-118), C83.12; Requirements for Wire-Wound Power-Type Rheostats (RETMA TR-133), C83.13; Requirements for Rigid Coaxial Transmission Lines—50 Ohms (RETMA TR-134), C83.14; and Requirements for Electrolytic Capacitors (For Use Primarily in Transmitters and Electronic Instruments) (RETMA TR-140), C83.15. . . . **The RETMA Engineering Department announced that the following standards were issued in December:** RS-171—High Voltage Ceramic Dielectric Capacitors, Class 2 (S.P. 445); RS-172—Fixed Composition Resistors (REC-116, S.P. 493); RS-173—Emergency Standby Power Generators for Microwave Systems (S.P. 504); RS-174—Audio Transformers for Electronic Equipment (TR-121, S.P. 512); RS-175—Audio Reactors (TR-122, S.P. 513); and RS-176—Pulse Transformers for Radar Equipment (TR-129, S.P. 515). JETEC Publication No. 9 "Summary of Registered Cathode Ray Tubes," is available from the RETMA Engineering Department at $2 per copy. The new publication lists all cathode ray tubes registered through December, 1956 from one inch to 30 inch sizes for radar, oscilloscope and television applications. The pertinent characteristics for each tube type with the sponsoring company are also listed. . . . **Col. E. L. White, former Chief of the Safety and Special Radio Services Bureau, Federal Communications Commission, on Jan. 1 joined the RETMA staff to direct a special informational program in connection with the Commission's publicly announced allocations study and hearing on frequencies from 890 mc.** Col. White is taking a two-month leave of absence from his position with Microwave Services, Inc. to direct the RETMA program which is sponsored by members of the Association's Microwave Section. The campaign is aimed at informing present and potential microwave

(Continued on page 98A)

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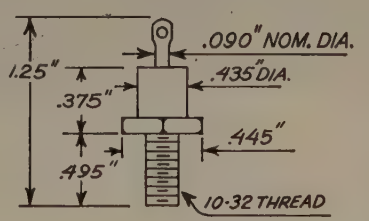


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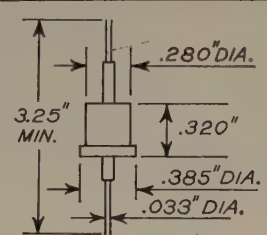
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CK846	100	1.0	0.002
CK847	200	1.0	0.002
CK848	300	1.0	0.002
CK849	400	1.0	0.002
CK850	500	1.0	0.002
CK851	600	1.0	0.002

Case Dimensions***



Type	Peak Inverse Volts*	Forward Current** Amps. 150°C Ambient	Forward Current** Amps. 100°C Ambient	Reverse Current (max.) at PIV mAdc at 25°C
CK840 (1N537)	100	0.25	0.5	0.002
CK841 (1N538)	200	0.25	0.5	0.002
CK842 (1N539)	300	0.25	0.5	0.002
CK843 (1N540)	400	0.25	0.5	0.002
CK844	500	0.25	0.5	0.002
CK845	600	0.25	0.5	0.002



*PIV ratings apply from −65°C to +150°C
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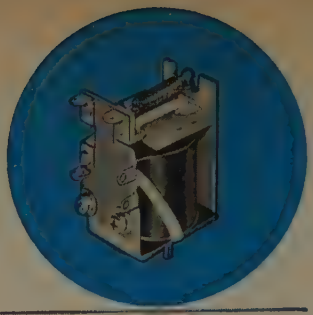
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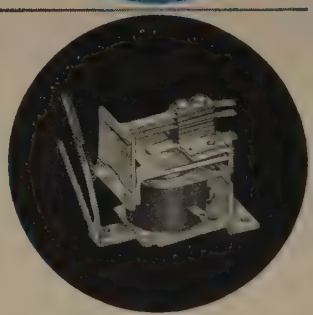
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Industrial Engineering Notes

(Continued from page 96A)

users of the vital importance of the FCC hearing (Docket 11866) and the necessity of advising the Commission of the frequency needs of the new and fast-growing microwave industry. The FCC hearing is scheduled to begin April 1. The FCC announced the forthcoming hearing as a means of reviewing all allocations above 890 mc with the purpose of proposing such changes as may be consistent with microwave and other developments and future use and requirements by fixed and mobile services. The Commission added that this is the initial step in an overall study of allocations in that portion of the radio spectrum to meet existing service needs and foreseeable developments in the use of microwave. In connection with the hearing, the FCC posed a series of 19 specific questions dealing with both the technical and operational aspects of microwave communications. The RETMA informational program will be supervised by a special committee of the Microwave Section under the chairmanship of Grant Woodside, of Motorola Inc.

Statistics

Based on a new statistical formula recently devised by the RETMA Marketing Data Department, as the result of estimating procedures developed in cooperation with industry and government sources, RETMA is now able to report accurately military electronics expenditures in all major categories of Defense Department procurement. Under its manager, W. F. E. Long, the RETMA Marketing Data Department, in utilizing its formula, estimates that electronic procurement during the fiscal year 1956 was $2.733 billion, and $632.6 million was expended during the first quarter of fiscal year 1957. Broken down into major procurement items, the report shows (in millions of dollars):

Budget Category	*Fiscal year 1956*	*First quarter 1957*
Aircraft	$925.0	$213.0
Ships and Harbor Craft	80.0	17.0
Combat Vehicles	9.5	1.0
Support Vehicles	5.8	.2
Guided Missiles	630.0	205.0
Electronics and Communications	770.2	130.0
Research and Development	265.0	66.0
Miscellaneous	47.5	.4
Total	$2,733.0	$632.6

Percentage-wise, the electronics portion of "aircraft" expenditures amounts to 34 per cent of the total amount spent for such procurement; "guided missiles," 23 per cent, and "electronics and communications," 28 per cent of the total amount expended for such procurements. In the first quarter of fiscal year 1957, the Marketing Data figures again show a 34 per cent slice of the "aircraft" expenditures went for electronics; 32 per cent of

(Continued on page 103A)

Industrial Engineering Notes

(Continued from page 98A)

the total "guided missiles" expenditures went for electronics, and 20 per cent of "electronics and communications" was used to procure electronics.

Year-End Review

Supporting the claim that it is one of the country's foremost growth industries, RETMA President W. R. G. Baker noted that the ever-expanding radio-electronics-television industry has increased in size by 15 per cent in 1956, and it is "predicted that 1957 will bring an added 10 per cent growth." In a year-end statement, the RETMA official also noted that "this young industrial giant approached the $5.9 billion mark in 1956 in terms of production and sales," and when the revenues from distribution, servicing and broadcasting are added, he said, "this figure nears the 12 billion level." Certain growing pains did not alter the growth path of the industry, Dr. Baker said; and he cited as an example the leveling off of TV receiver production. Still, he said, "the Marketing Data Department shows that more than 7 million sets were sold, making 1956 one of the best four years in television production history." Continuing his analysis of the electronic industry's production, sales, and research activities during 1956. Dr. Baker said: "The uneasy international situation has triggered an increase in military electronics research and development. In 1956, military electronics sales reached the "2.7 billion level —an increase of 10 per cent over 1955—and accounted for nearly half of the total industry sales. Electronics is playing an ever-increasing vital role in the complex weapons systems which will be decisive in preserving United States military strength and political freedom. Looking to the future, it is estimated that even though the total defense budget may remain relatively stable in years to come, the percentage of defense spending for electronics will probably increase by 100 per cent in the next 10 years. It should be noted that historically there always has been an important cross-pollination of electronic developments between the military and the industrial fields. Electronic devices developed for the military have found applications in the commercial field and vice-versa. Contrary to television receiver sales, radio sales in 1956 increased about 20 per cent over the 1955 figures. However, car radio sales, tied to automobile production, declined 25 per cent in the past year." . . . **"Radio is being harnessed to industrial and other business uses on a scale never before known," Federal Communications Commission Chairman G. C. McConnaughey said in issuing a year-end statement.** "The one and a quarter million transmitters which now dot or move about our landscape help visualize the extent to which radio has become an integral part

(Continued on page 106A)



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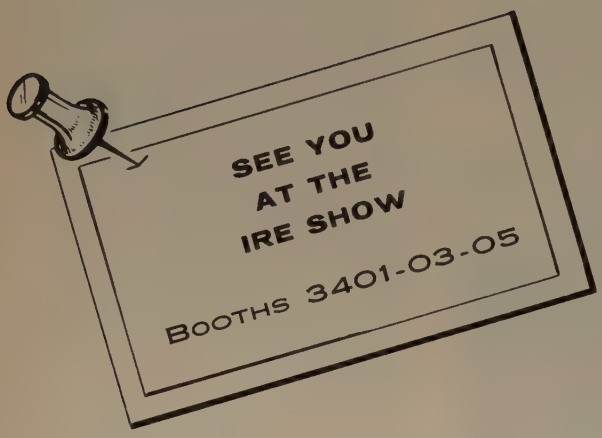
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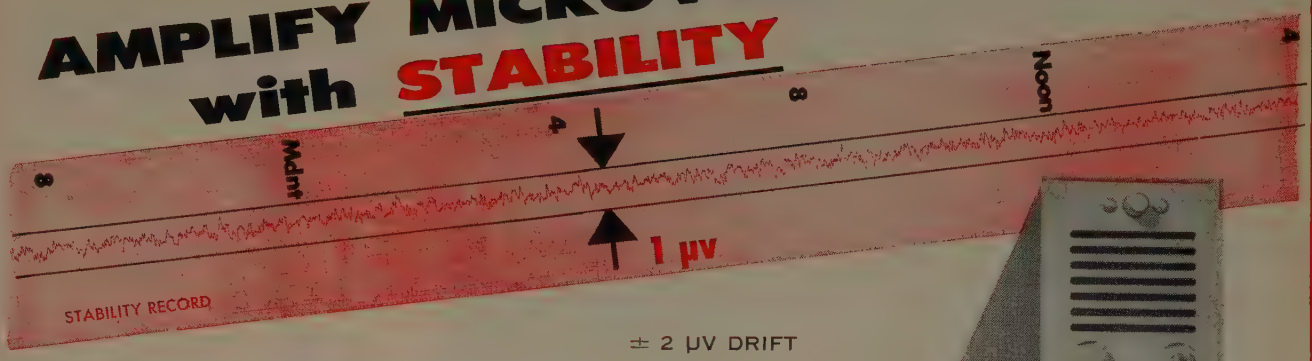
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5725 KEARNY VILLA ROAD · SAN DIEGO 11, CALIFORNIA · BROWNING 7-6700

KINTEL
[KAY LAB]

FOR DRIFT-FREE DC INSTRUMENTATION

AMPLIFY MICROVOLTS with STABILITY



± 2 μV DRIFT

INTEGRAL POWER SUPPLY

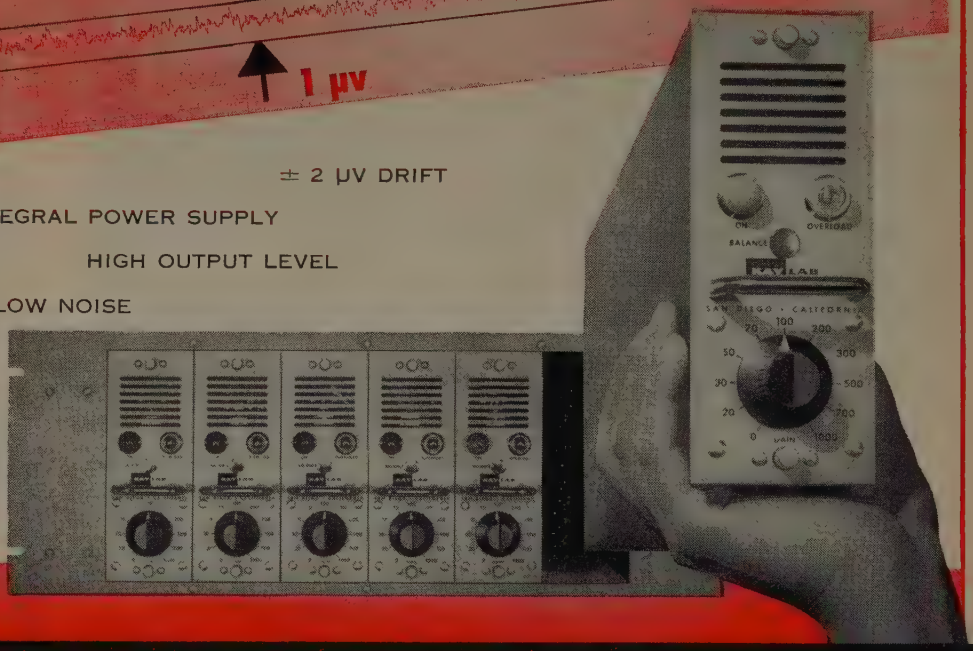
HIGH OUTPUT LEVEL

EXTREMELY LOW NOISE

BROAD BANDWIDTH

10 ACCURATE GAIN RANGES

HIGH INPUT IMPEDANCE



The **KINTEL** Model 111 amplifier provides maximum stability and the lowest drift of any commercially available broadband d-c amplifier. It is the end result of years of research in the field of chopper stabilized broadband d-c amplifiers. Thousands of **KINTEL** amplifiers are in daily use.

The Model 111 incorporates **KINTEL's** proven chopper amplifier circuitry and provides ten extremely precise, feedback controlled gain ranges. Several feedback loops assure high accuracy, stability and uniform frequency response. The completely new and unique circuit provides rapid recovery from severe overloading and unsurpassed dynamic performance—unaffected by load or gain changes.

The Model 111 is available in a single-unit cabinet or in a six-unit rack-mountable module. The amplifiers are extremely compact; the six-unit module occupies only a 19-inch rack width.

APPLICATIONS: The Model 111 is ideal for permanent low level d-c instrumentation, telemetering, or as a strain gage amplifier, transducer amplifier, scope preamplifier, recorder driver amplifier, or general purpose laboratory amplifier.

SPECIFICATIONS

Gain	0, 20, 30, 50, 70, 100, 200, 300, 500, 700, 1000
Gain Accuracy	± 1% DC to 2 KC
Input Impedance	100,000 Ω
Output Capability at DC	0 to ± 35 V where R_L > 1000 Ω 0 to ± 40 MA where R_L is 10 to 400 Ω
Output Impedance	Less than 1 Ω in series with 25 μh
Equivalent Input Drift	± 2 μv with regulated line
Equivalent Input Noise	0 to 3 cps, less than 5 μv peak to peak 0 to 750 cps, less than 5 μv RMS 0 to 50 kc, less than 12 μv RMS
Chopper Intermodulation	Less than 0.1%
Linearity	Better than 0.1% to 2 KC
Frequency Response	± 3% (0.3 db) DC to 10 KC, less than 3 db down at 40 KC

Power Requirements:	
Amplifier	117 V—60 cycles—70 VA
Cabinet	117 V—60 cycles—15 VA
6 Unit Rack Adaptor	117 V—60 cycles—45 VA
Dimensions: Amplifier Unit	2⅞" wide, 7⅝" high, 14⅝" deep
Rack Adaptor for 6 Units	19" wide, 8¾" high, 18¼" deep
Net Weight—Amplifier	11 pounds
PRICE: Amplifier Unit	$550.00
19-inch Rack Adaptor for 6 amplifier (with fans and connectors)	200.00
Cabinet for single amplifier (with fan and connector) is available.	

...the Standard in chopper-stabilized instruments



STABILITY *locked in!*

WITH CHOPPER AMPLIFIERS

KINTEL
[KAY LAB]

Representatives in all major cities.

5725 KEARNY VILLA ROAD, SAN DIEGO 11, CALIFORNIA · BROWNING 7-6700.

IMC...DYNAMOTORS

for MISSILES and TELEMETERING



Induction Motors Corp. has developed another new dynamotor series to meet increasingly critical missile and telemetering requirements. The 1500 Frame DC series is designed for applications where light weight, compactness, high reliability and exceptional resistance to vibration and shock are essential.

The BD 1509D shown meets military specifications with regard to resistance to corrosion, salt spray, sand and dust, and other environmental influences.

SPECIFICATIONS · BD1509D

SIZE: 1½" x 1½" x 3".

POWER OUTPUT: 10 w continuous; up to 25 w, depending on duty cycle and cooling.

WEIGHT: 1 lb.

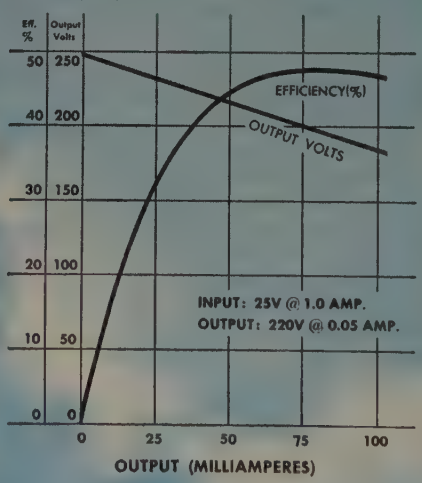
LIFE: 100 hrs. brush life at 50,000 ft.

AMBIENT TEMPERATURE RANGE: −40°C to + 71°C standard.

VIBRATION: 3 g's from 5-600 cps along 3 mutually-perpendicular axes.

CENTRIFUGE: 30 g's in any direction.

MECHANICAL SHOCK: 40 g's in any direction.



Other units in the new 1500 Frame DC series are available in varying voltage outputs to meet a wide range of humidity, temperature, vibration or altitude requirements. Motor design and application consulting service available on request.

IMC

Visit our exhibit — Booth 2229 at the Radio Engineering Show

Induction Motors Corp.

570 Main St., Westbury, L. I., N. Y. Phone EDgewood 4-7070

Industrial Engineering Notes

(Continued from page 103A)

of the American way of life," he said. The FCC Chairman listed 14,000 industrial stations with 116,000 transmitters; 17,000 power and petroleum stations with 143,000 transmitters; and 1,400 forest products stations with 13,500 transmitters. In the aviation group, 37,000 commercial and private aircraft are radio equipped and served by 4,300 land and other transmitters authorized by the FCC, Mr. McConnaughey said. In addition, "more than 13,500 fixed and mobile transmitters are employed by the Civil Air Patrol." On the water, nearly 60,000 ships use radio to communicate with one another and with more than 2,100 shore transmitters. About 3,000 ships are radar-equipped, he said. As far as land transportation is concerned, 5,000 taxicab stations represent the use of 103,000 transmitters; 1,800 railroad stations have 59,000 transmitters; 200 passenger bus systems operate 3,800 transmitters; and 1,700 trucking stations require 25,500 transmitters, Mr. McConnaughey said, "Nonbroadcast operations dwarf radio and television services numerically," the FCC Chairman said. "Contrasted to less than 4,500 broadcast stations, not counting their auxiliaries, there are nearly 360,000 other radio station authorizations, a 200 to 1 ratio."

NO CAMS . . . NO GEARS

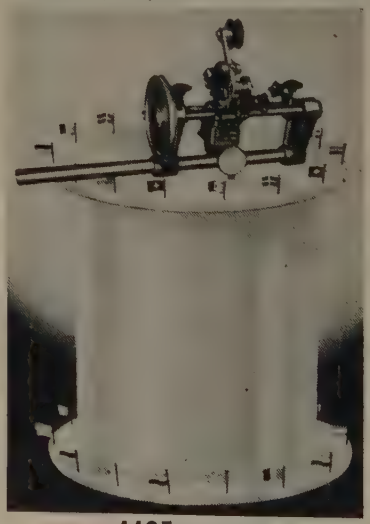
NO LOSS of time with

WFA **AUMANN**

High Precision

Layer Winding Assemblies

Infinitely Adjustable to Wire Size



Booth **4405** at the IRE Show

INDUSTRIAL WINDING MACHINERY CO.

Henry W. Roehrig

Suite 3410, 120 Wall St., N.Y.C. 5

WHitehall 3-1754



SCINTILLA DIVISION
Sidney, N. Y.

Electrical Connectors—standard and special types. Benseal protected wiring assemblies.

BENDIX RADIO DIVISION
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Communications and navigation equipment (aircraft radio, airborne radar, VOR, transmitters & receivers) for aircraft. Also automotive radio.

ECLIPSE-PIONEER DIVISION
Teterboro, N. J.

Synchros, low-inertia motors, motor generators, rate generators, gyros, radar, ordnance synchros, mechanisms for Polar Path® compass coupler.

RED BANK DIVISION
Eatontown, N. J.

Ruggedized Klystron tubes, cathode discharge tubes, Transistors, power supplies including missile application.

PACIFIC DIVISION
North Hollywood, Calif.

Radar, telemetering, radio-telephone, sonar.

Bendix
AVIATION CORPORATION

✓ **LOW TIME JITTER**

✓ **HYDROGEN RESERVOIR**

are TOP features you'll find in these NEW

HYDROGEN THYRATRONS



Outstanding for compactness, ruggedness, long life and dependability . . . in network discharge service

The new 6587 and 5957/E-37B are advanced developments of *Kuthe* . . . foremost producer in the field.

Both types include an internal hydrogen reservoir across the filament . . . to produce and maintain constant hydrogen pressure . . . to increase the life of these high-quality tubes.

Low time jitter and the power rating of the 6587 make this type ideal for Moving Target Indicator applications.

The 5957/E-37B, a rugged, miniaturized version of the 4C35 (with 30% of its volume) is especially suited for compact airborne systems.

For complete engineering data, write to Kuthe, Dept. W-137A.

Principal Electrical-Mechanical Data and Ratings:

	6587	5957/E-37B
Heater voltage	6.3 volts ±7.5%	6.3 volts ±7.5%
Heater current	11 amperes	6.5 amperes
Reservoir	Conn. across Htr.	Conn. across Htr.
Minimum heating time	3 minutes	3 minutes
Over-all length	7.25" max.	4.375" max.
Greatest diameter	2.56" max.	1.56" max.
Peak anode v. forward	16 kv max.	8.0 kv max.
Peak anode current	325 amps. max.	83 amps. max.
Average anode current	225 ma. max.	100 ma. max.
Operation factor	3.9 x 10^9	2.5 x 10^9
Maximum tad	0.60 μs	0.50 μs
Maximum Δ tad	0.10 μs	0.10 μs
Maximum tj	0.005 μs	0.01 μs

"World's Largest Manufacturer of Hydrogen Thyratrons"

Kuthe Laboratories, Inc.

An Associate of
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Whom and What to See at the Radio Engineering Show

(Continued from page 110A)

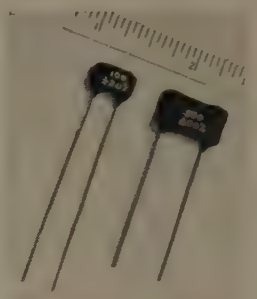
Aeroprojects Inc., Booth 1913
310 E. Rosedale Ave.
West Chester, Pa.

W. C. Potthoff, D. D. Kirkpatrick, ▲ C. DePrisco, E. E. Weismantel, E. B. Webb

SONOWELD, ultrasonic welding equipment
SONOBOND, ultrasonic soldering equipment
SONOBRAZE, ultrasonic brazing equipment

Aerovox Corporation
New Bedford, Mass.
Booths 2601-2607

▲ Louis Kahn, ▲ Robert R. Warriner, Paul M. Beard, Cyrus Stonehill, ▲ Frank Campisano, Jack Roskilly



Dipped-Mica Capacitors

New Plastic-Coated, Dipped-Mica Capacitors; New "CERAFIL" Ceramic Capacitor; New Telemetering Filters; New Right-Angle Tube Sockets; New Paper Tubular Capacitors; New Printed-Wiring.

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Charles M. Donoho

Variable resistors, vibration test machines, magnetic amplifiers, potentiometers.

Airborne Instruments Lab.
160 Old Country Road,
Mineola, L.I., N.Y.,
Booths 3508-3512

▲ J. F. Bisby, ▲ K. Collins, ▲ A. Hendler, ▲ W. Landaver, ▲ M. Labenbaum, ▲ T. V. Schiavoni, S. Shapiro, J. Stasch, ▲ A. Stiefel, ▲ G. Thogersen

Antenna test equipment—recorders, positioners, oscillators. Automatic noise figure indicator equipment. Microwave Crystal Tester, test receiver, IF attenuators, integrating amplifier, radiation monitoring equipment, automatic gear gage and grinding control.

Airflyte Electronics Company, Booth 3829
535 Avenue A
Bayonne, New Jersey

Milton Feinman, Richard A. O'Brien, Ben Novy, Cort Smith, Michael Siwiec, Michael Steinman

*Binary Coded Commutators and Rotary Segmented Switches for the ultimate in precision, life, and miniaturization. Slip Ring and Brush Block Assemblies. Potting and Encapsulation Services

(Continued on page 113A)

* Indicates new product.

▲ Indicates IRE member.

Whom and What to See at the Radio Engineering Show

(Continued from page 112A)

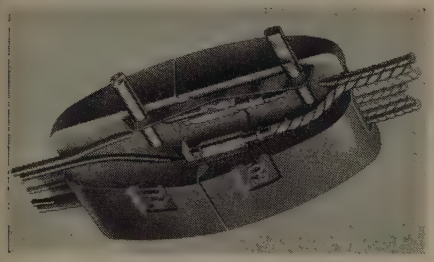
Air-Marine Motors, Inc., Booth 2315
369 Bayview Avenue
Amityville, Long Island, N. Y.

David H. Thomas, Arthur W. Forsberg, Oskar W. Giesecke, Roland B. Schattle, Dave Fleming

*Low Cost Remote Positioning Device, a new design concept in repeater units. Small input torque—high output torque. Accuracy within ±½°.

Airpax Products Co.
P. O. Box 132 (Middle River),
Baltimore 20, Md.
Booth 2505

▲H. A. Cook, W. D. Heisler, ▲D. H. Holdt, M. Monaco, ▲H. W. Patton, W. H. Pierce ▲F. H. Rockett, E. R. Shawn

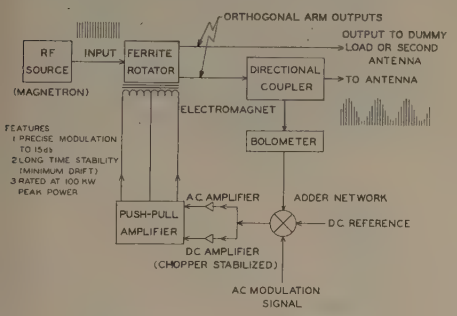


High Vibration Chopper

High vibration chopper, chopper test sets, expanded scale and wide band Magmeter frequency detectors, miniature pulse transformers and circuit breakers, and instrument Ferrac magnetic amplifiers.

Airtron, Inc.
1107 W. Elizabeth Ave., Linden, N. J.
Booth 3318

▲David Ingalls, ▲Leonard Pincus, ▲Tore N. Anderson, ▲Robert Hautzik, ▲R. C. Kolts, ▲Robert Terry, ▲E. Hensperger, Leo Mayberry, L. Trummel, B. Leroe, O. Kress.



High Power Ferrite Attenuator

Microwave Ferrite Components • Antenna Feeds • Rotary Joints • Flexible Waveguide Assemblies • Precision Cast Mixers, Duplexers, and Hybrids • Directional Couplers • Double Ridge Waveguide • Lightweight, High Power Terminations.

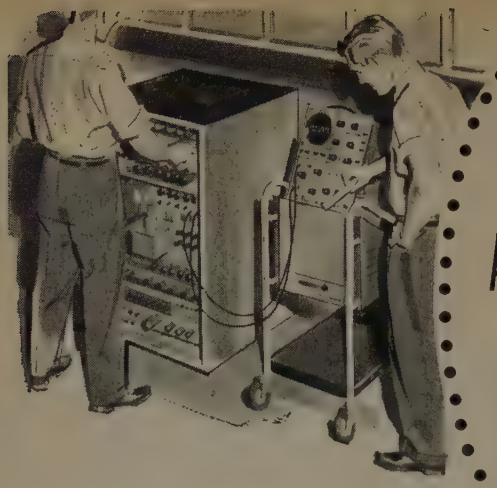
(Continued on page 114A)

* Indicates new product.
▲ Indicates IRE member.

Be sure to visit all four floors. Every exhibitor has something to offer you!



McCoy ELECTRONICS COMPANY
MT. HOLLY SPRINGS, PA.
DEPT. P-3
Phone 376 and 377



Your Tektronix Field Engineer as an

APPLICATIONS AID

Sharing his applications know-how with you is another of his many helpful functions.

SPECIFIC TASKS

When you have a job to do that's a little different, and you can't quite see how your oscilloscope ties into it, call on your Tektronix Field Engineer. He'd like a try at saving you time and effort through use of your oscilloscope. If there is a tie-in between your work and your oscilloscope, the connection is probably filed between his ears. It will very likely pop out as he becomes aware of the circumstances.

EVERYDAY UTILITY

Many routine checks and measurements can be performed with greater ease and more accurate results with the aid of your oscilloscope. Information presented in the form of a cathode-ray-tube display is often more enlightening than a collection of inanimate figures. Discussing measurement techniques with your Tektronix Field Engineer can be profitable. Encased in his handsome headbone may be the very idea that will help you get better answers in less time.



A REAL FRIEND

Look to your Tektronix Field Engineer for help with any problem related to the instruments he knows so well. His skills and knowledge, added to your own, can make your efforts more productive. Let him show you how helpful he can be.



Tektronix Field Offices: Albuquerque, N. M.—Baltimore, Md.—Bronxville, N. Y.—Cleveland, Ohio—Dallas, Texas—Dayton, Ohio—Elmwood Park, Ill.—Houston, Texas—Los Angeles, Calif.—Menlo Park, Calif.—Minneapolis, Minn.—Newtonville, Mass.—Philadelphia, Pa.—Phoenix, Ariz.—Syracuse, N. Y.—Union, N. J.—Willowdale, Toronto, Ontario.

Tektronix Engineering Representatives: Bivins & Caldwell, High Point, N. C. and Atlanta, Ga.—Hawthorne Electronics, Portland, Ore. and Seattle, Wn.—Hytronic Measurement Associates, Denver, Colo.—Arthur Lynch & Associates, Fort Myers, Fla.

Tektronix is represented in seventeen overseas countries by qualified engineering organizations.

TEKTRONIX, INC., P. O. BOX 831, PORTLAND 7, ORE.

Whom and What to See at the Radio Engineering Show

(Continued from page 113A)

Aladdin Electronics
Div. of Aladdin Industries, Inc., 719 Murfreesboro Rd. Nashville 10, Tenn.
Booth 1816

▲ Fred G. Basler, ▲ Albert S. Daddario, ▲ Harold M. Greenhouse, ▲ Lester E. Hill, ▲ Charles M. Sutherland, ▲ William W. Stifler

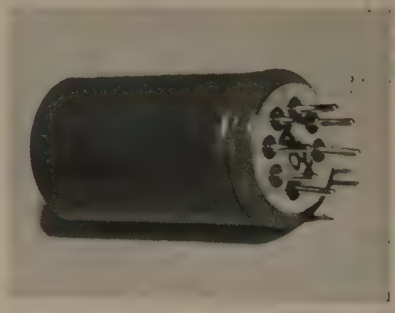


Micro-Miniature* Pulse Transformer Line; Pulse Transformer Encyclopedia for Circuit Designers Listing 600 Sets of Performance Characteristics; Ferrite-Core Inductors; IF and RF Transformer and Discriminators.

Alden Electronic & Impulse Recording Equipment Co., Booth 1612
P.O. Box 125—Washington St. Westboro, Mass.
E. D. Cross
Recorders, scanners, facsimile systems

Alden Products Co.
117 N. Main St., Brockton 64, Mass.
Booths 1614, 1616

▲ John Alden, Nelson Hearn, Malcolm Partridge, Edward Oxelius



Multi-Contact Umbilical Missile Connector

Alden "IMI" (Integrally Molded Insulation) Connectors providing first major breakthrough in connector reliability since potting, and packaging components for plug-in unit construction of electronic equipment.

Alfax Paper and Engineering Co., Booth 1610
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S. C. Sviokla
Recording paper

(Continued on page 116A)

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Rugged E-I Compression Seals are the industry's standard for superior performance in commercial and military service. Practically indestructible, they provide the maximum immunity to shock, vibration and temperature changes.

Available in miniature or sub-miniature types, these super-dependable hermetic seals are supplied in economical standard types to meet practically any sealing requirement.

Keyed to your electronic future...

E-I GLASS-TO-METAL SEALS*



For complete information on the E-I line or recommendations on particular requirements, call or write:

ELECTRICAL INDUSTRIES

44 SUMMER AVENUE, NEWARK 4, N. J.

E I ®

**Patents Pending—all rights reserved*

Single Lead Terminals—Available in standard or custom designs.

Plug-in Connectors—for vibrator, chopper, lock-in and noval sockets.

Transistor Closures — Standard sealed bases, cans and diode closures available.

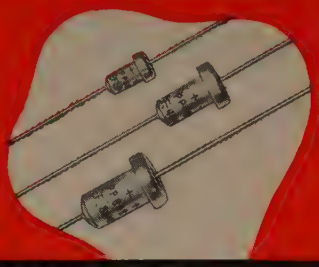
Multiple Headers—for every hermetic sealing requirement.

See us at the IRE Show!
Booths 2526-2528

FANSTEEL

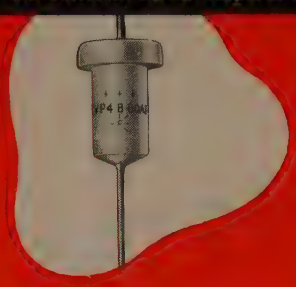
DEPENDABLE

Tantalum Capacitors



Series PP, for normal temperature ranges

Series VP, for excessive vibration or shock requirements



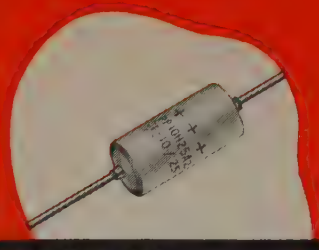
Series PP, VP and HP are also available with insulated cases.



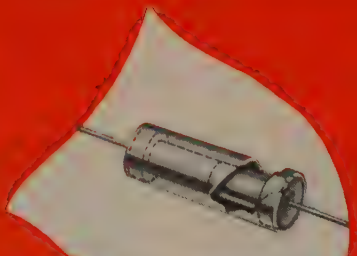
Series HP, for high ambient temperatures (to 125°C) and for vibration resistance



STA Solid Tantalum. Voltage ranges up to 30 volts, D-C. Unusual stability over a wide temperature range



Hermetically sealed capacitors to special order



Special configurations to your order

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AT THE I.R.E. SHOW

FANSTEEL METALLURGICAL CORPORATION
North Chicago, Illinois, U.S.A.

C573A

TANTALUM CAPACITORS . . . DEPENDABLE SINCE 1930

Whom and What to See at the Radio Engineering Show

(Continued from page 114A)

Alford Manufacturing Co., Inc.
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Booth 1623

▲ Andrew Alford, ▲ Chester B. Watts, Jr., David P. Flood, ▲ Harold H. Leach.



Automatic RF Impedance Plotter

Television Broadcast Transmitting Antennas, Diplexing Filters, Diplexing Bridges, Coaxial Switches, Transmission Line Tapers and Precision Loads, Hybrids and Slotted Coaxial Measuring Lines.

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J. H. Creede, J. P. Martin, R. E. Burket, J. W. Hale, W. J. Heintz, W. J. Wells

Complete line of electrical steels in various commercial forms.

Allen-Bradley Co.
114 West Greenfield Ave., Milwaukee 4, Wisconsin
Booths 3706-3708

▲ H. M. Schlicke, ▲ L. Beaudoin, ▲ E. Schwartz, F. Blomdahl, R. Hower, B. Tellkamp, A. Pfister, C. Dickinson, C. Water, ▲ W. W. Garstang.

Allen-Bradley "new idea" products consist of a new ¼ watt insulated, hot-molded carbon composition resistor; a new potentiometer similar to the famous Type J in appearance, but rated at 2-watts at 100°C, derating to Zero at 150°C. Other new products consist of hermetically sealed composition resistors; the type H, 5-watt potentiometer for industry electronic applications and new full round flared yoke cores for 110° deflection tubes and color.

Allied Chemical & Dye Corporation, General Chemical Division, Booth 4242
40 Rector St.
New York 6, N.Y.

C. P. Berdell, G. T. Stribling, Clifford Strugek, S. I. Hoddeson

A new line of special high purity electronic-grade chemicals, especially developed for production of semi-conductors, other electronic equipment.

Allied Control Co., Inc., Booth 2120
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New York 21, N.Y.

Ralph Ferry, John Vetrano, Frank LaChapelle

New Relays: CH-12D 4PDT 10 amp. 30G, 2000 cps; GK bifurcated-contact miniature telephone; TH micro miniature SPDT; hermetically sealed S & H polarized; 1 to 6 Pole S & H cradle telephone.

Alpha Metals, Inc., Booth 4319
56 Water Street
Jersey City 4, N. J.

H. Shonberg, H. Hertzog, M. Boyle, ▲ F. C. Disque, H. Cohn, G. Coleman, T. Fisher, J. Kennedy, W. Hasek, H. Tang, R. Hillsinger, P. Tort, E. Edrick, N. Bilsky

A working model which dramatizes the speed effectiveness of automatic soldering with preformed solder rings will be featured. Also on display will be the complete line of solders, fluxes and high purity metals.

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Booth 4321

Peter Bercoe, A. E. Bernardik, Howard B. Saltzman, Charles Kirschbaum, Donald Rappaport, Sam Schaeffer, Raymond Ives, N. Frost, S. Kaplan, D. Litt, A. Louro

"Altemp" high temperature teflon wire plus *prototype "special facilities" department. Complete MIL spec and commercial line of electronic wire and cable.

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Chicago 31, Ill.

Robert C. Komarek, Howard L. Hoffman, Gerald Fine, Milton H. Miller, Louis Perlman, Ted Hendel, Mason R. Burgh, James E. Washington, Charles G. Furrer, Julian Silverman

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Owen I. Haszard

Microwave cavity oscillators, amplifiers, microtuning devices, microwavemeters.

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Walter E. Allan, William J. Stanley

Seamless electronic prongs, transistor shells, resistor end caps, screw shells, wire and clip terminals, starting cans, fuse caps, plug blades, wire tips, deep drawn cups and shells, radio tube grid and plate terminals, loctal base shells, condenser cans, heavy copper electronic anodes and piezo electric quartz-crystal cans.

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Frank W. Kuhn, B. Vincent Benton

The Latest By "American Beauty"—The "T-12" Transformer Type Electric Soldering Iron For Precision Soldering.

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Superpressure Equipment, Testing Equipment

American Lava Corp.
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Chattanooga 5, Tenn.
Booths 3901-3902

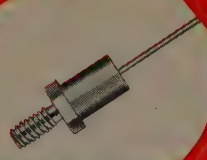
Frank Kelly, Douglas Coleman, Wm. Brown, A. C. Kilberg, D. E. Denham

Complete line of electrical insulation—Scotch brand electrical and magnetic tape, resins—AlSiMag ceramics—Irvington plastic, varnishes, coated cloth—mica Lamicoid, Isomica and Micanite products.

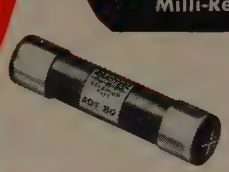
(Continued on page 118A)

* Indicates new product.
▲ Indicates IRE member.

FANSTEEL
Dependable Rectifiers



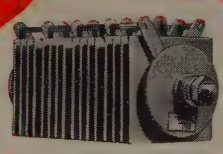
Silicon Rectifiers



Selenium Milli-Rectifiers



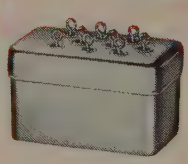
Selenium Industrial Power Rectifiers



Selenium High Temperature Power Rectifiers (to 150°C)



Battery Chargers and Power Supply Units



Special Hermetically Sealed Units to Special Order

CHECK
BOOTH 4021
AT THE I.R.E. SHOW

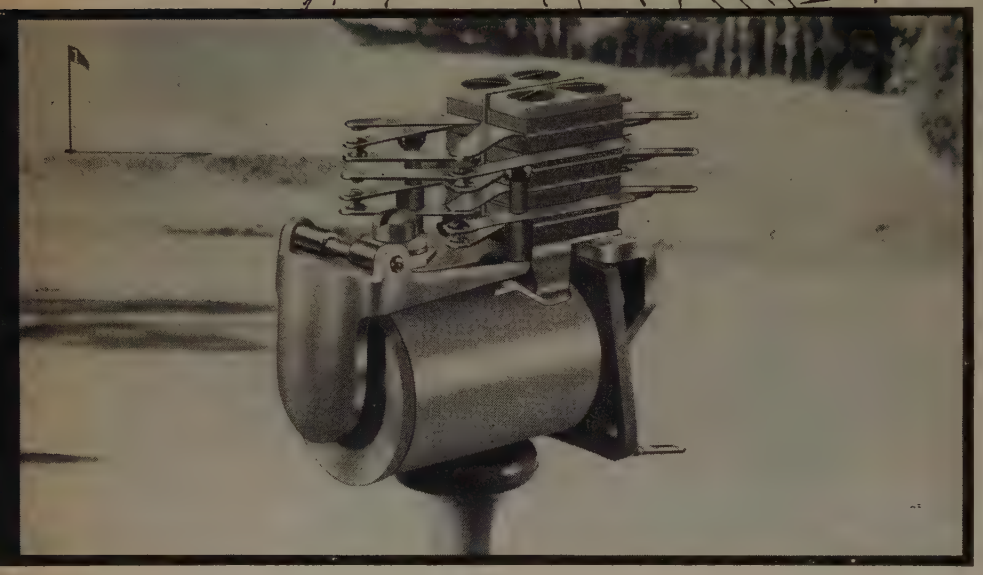
E573A

FANSTEEL METALLURGICAL CORPORATION
North Chicago, Illinois, U.S.A.

DEPENDABLE RECTIFIERS SINCE 1924

He's playing golf with the man from PHILLIPS"





COIL CHARACTERISTICS:
Operating Voltage: up to 230 volts D.C.
Resistance: up to 14,000 ohms. Single or double wound.
Operating Current: 0.004 Amps., minimum
Operating Time: 0.003 Secs., minimum

CONTACT ASSEMBLY:
All forms A, B, or C. Single or double pile-up. Code #4 Palladium contacts, standard. Other contacts available.

MOUNTING:
Two 4-40 tapped holes on 3/8" centers

what's your handicap For lightning calculations of high speed computers and data processing equipment — for lightning responses of guided missiles and modern aircraft, the new Type 9 relay meets all the critical requirements. A miniature telephone-type multi-contact relay, the Type 9 combines speed of action, reliability and high resistance to shock and vibration. It is available in a wide choice of contact materials and with a maximum of 18 springs (9 per pile-up). Springs are phosphor bronze for long life. Each unit is individually adjusted to insure conformance with rigid operating specifications. Type 9 is available as a hermetically sealed unit, measuring 1" x 1⅝ x 2", only slightly larger than the regular relays.

Work with your man from PHILLIPS on any relay problem — multi-contact, power, hermetically sealed, A.C. or D.C.

Visit us at booth No. 2714 Second Floor IRE SHOW

HERMETIC SEALS, MULTI-CONTACT, POWER, HERMETICALLY SEALED RELAYS, ACTUATORS

PHILLIPS

PHILLIPS CONTROL CORPORATION . . . JOLIET, ILLINOIS

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Whom and What to See at the Radio Engineering Show

(Continued from page 117A)

American Machine & Foundry Co.
1101 North Royal St.
Alexandria, Va.
Booths 1506-1508

D. White, R. Young, J. DeClue, A. Vuozzo, H. Salander, R. Granchelli, S. Valovic, B. H. Dean, G. Berklund

*AMF "Digitron"—a dynamic display of selected symbols on a cathode-ray tube. *Power Transient Analyzer. *Frequency Meter.

The American Metal Co., Ltd., Booth 4008
61 Broadway
New York 6, N.Y.

A. E. Beck, E. Carlson, E. Eriksen, H. Schleicher, G. C. Van Tilburg, F. Wasser

Copper, germanium & selenium raw materials for fabricators.

American Metrix Corporation, Booths 3025-3026
40 Haddon Avenue
Camden, New Jersey

Andre Wehrung, G. Friedrichs

New Products include a line of rugged, precision ½ and 1% Panel Meters of the D'Arsonal Galvanometer type and the Iron Vane Type. Also included are new multimeters and sweep generators.

American Molded Products Co.
2727 W. Chicago Ave., Chicago 22, Ill.
Booth 4116

Arnold P. Hultgren, Arthur Weyrich, Robert Hauser.

STOCK NYLON BOBBINS



- NO MOLD COST
- IMMEDIATE DELIVERY ON POPULAR SIZES
- WRITE FOR NEW CATALOG

BOOTH NO. 4116

American Molded Products Co.
2729-39 W. CHICAGO AVE. • ARmitage 6-3235
CHICAGO 22, ILL.

See the new automatic self threading magnetic tape cartridge. Designed so the tape conceals itself to make it tamper proof when not in use.

American Plastics Corp., Booth 4115
342 Madison Avenue
New York 17, N. Y.

Walter J. A. Connor, John A. Parsons, Bill Vega, Walter Opp, Marshall Sangster, Gus DeVera

Multiple-shot injection molding, a new method for producing plastic parts requiring permanent identification. With this process numbers, letters, symbols or other indices are molded into the part, *not* imprinted or filled in.

American Smelting & Refining Co., Federated Metals Division, Booth 4422
120 Broadway
New York 5, N. Y.

D. Knapp, T. H. Heemstra, H. C. Sohl, E. R. Bergin, R. Philion, A. L. Lee, J. D. Allen, Jr., Dr. Perkins, W. Klein, E. Yeck, E. Friedlander

*Activated Liquid Rosin Flux (high speed production soldering): *RTS 300 Activated Rosin Core Solder; Castomatic Bar Solder (printed circuits); Indium (transistors); Selenium (rectifiers); Cadmium (plating).

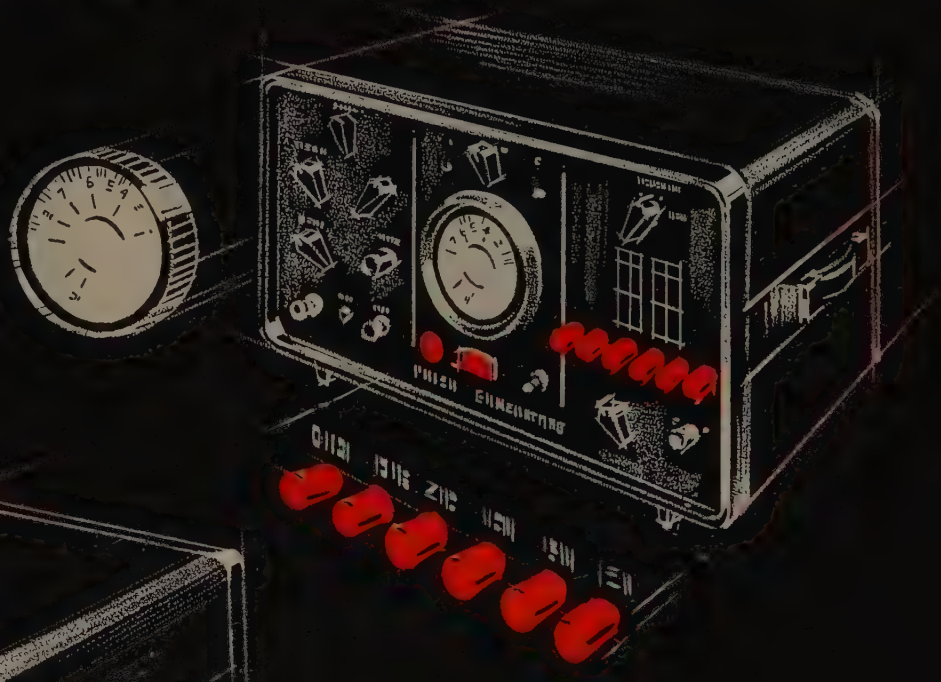
(Continued from page 122A)

1st Floor—Equipment
2nd Floor—Component Parts
3rd Floor—Instruments & Components
4th Floor—Production

6 ready now

TYPE 404

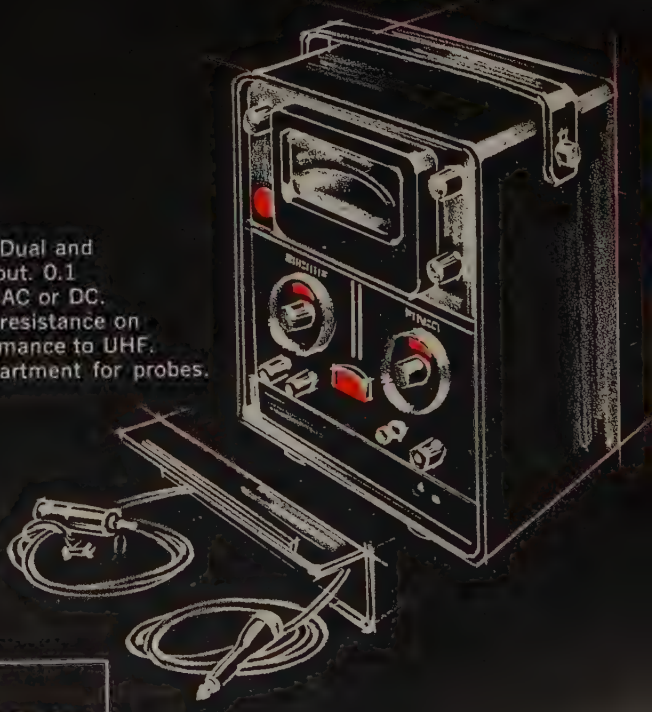
Jitter-free, hard-tube circuitry pulse generator. Pulse repetition rates up to 100,000 pps.





TYPE 405

AC-DC VTVM. Dual and differential input. 0.1 volt full scale AC or DC. 121 megohm resistance on DC. AC performance to UHF. Storage compartment for probes.



TYPE 410

High gain DC amplifier with 7 millimicrosecond rise time. High duty cycle calibrated sweeps. 24 KV accelerating potential. Building Block construction allows choice of performance characteristics.

WARRANTY

Every instrument in the DuMont 400 Series carries a five-year guarantee.

DUMONT®

Technical Products Division, Allen B. Du Mont Laboratories, Inc., 760 Bloomfield Ave., Clifton, N. J., U.S.A.



Honeywell Aero's MIG (Miniature Integrating Gyroscope). Weight: 0.5 lbs. Size: 1.75 inches in diameter. Performance: equal to gyroscopes 3 times larger. Just one of more than 70 new Honeywell Aero products put into production during the past year.

RESEARCH, DESIGN AND DEVELOPMENT ENGINEERS

WHAT WILL YOU THINK OF NEXT?

If it's in aeronautical controls, there are exciting opportunities for you at Honeywell. Honeywell Aero's outstanding development programs now in progress offer exceptional opportunities for research, design and development engineers in the following fields:

INERTIAL GUIDANCE • DIGITAL COMPUTERS • FLIGHT CONTROL SYSTEMS • LIQUID MEASUREMENT SYSTEMS • VERTICAL AND RATE GYROS • STABILIZED PLATFORMS • INLET AREA CONTROLS • JET ENGINE CONTROLS.

At Honeywell, you'll work with your own design team which includes a technician, a model maker, an evaluation engineer and a draftsman. You'll guide your own project from start to finish, get quick recognition and advancement.

You start with a first rate salary and because Honeywell rewards talent as well as experience, increases are based primarily on merit. There's a liberal program of extra benefits, too.

Positions are now open in Minneapolis, Minnesota, city of lakes and parks, which offers exceptional cultural, recreational and educational advantages for your whole family.

Production Engineers. There are also outstanding opportunities for production engineers in the above fields.

WRITE TODAY! If you are interested in a career at Honeywell, call collect or send your résumé to Bruce D. Wood, Technical Director, Dept. TA3A Aeronautical Division, 1433 Stinson Boulevard, N. E., Minneapolis 13, Minnesota.

MINNEAPOLIS **Honeywell** Aeronautical Division

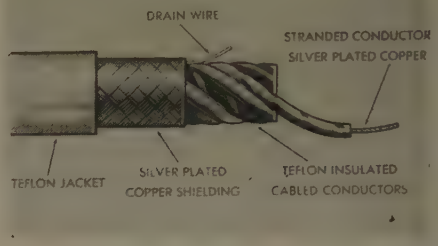
Whom and What to See at the Radio Engineering Show

(Continued from page 118A)

American Super-Temperature Wires, Inc.
194 Nassau St., Princeton, N.J.

Booth 4520

Leroy C. Tourville, Frank E. Dickson, Robert Worrall, James Kenny, Marshall Moon, Jack Heaslip, John Mancino, Richard D. Hoyt, Oakley F. Hoyt



Teflon† insulated multiconductor miniature shielded and jacketed cables. Teflon insulated magnet wires to size #50. Teflon insulated hook-up wires. Teflon tubing.

†Dupont trade name for Polytetrafluoroethylene.

American Television & Radio Co.
300 E. Fourth St.
St. Paul 1, Minn.

Booth 2834

A. A. Goffstein, L. Rocke, A. W. Pleasanton, T. Marchiano

Vibrators, inverter vibrators, power supplies.

American Time Products, Inc.
580 Fifth Avenue,
New York 36, N. Y.

Booth 3926

J. N. Heed, Lawrence Hammenway, ▲ Frank Dostal, ▲ Joseph Bodow, Robert Poillon



Precision Frequency Standards and Forks in various forms (10 to 20,000 cps) for use as references and in control and measuring systems requiring high accuracy.

Amperex Electronic Corp., Booths 2522-2524
230 Duffy Ave.
Hicksville, L. I., N. Y.

Frank Randall, ▲ Irwin Rudich, Charles Roddy, Arnold Peterson, ▲ Sol Gertzis, Walter Sandberg.

Diodes & Transistors, *Industrial & Communication Tubes, *Military Type Tubes, Line of Recent Additions to Line of Special Purpose Tubes (Hi-Fi, Computer Types, Indicator Tubes, etc.)

(Continued on page 126A)

* Indicates new product.

▲ Indicates IRE member.

nother major stride forward in communication.
om the research and development laboratories
Collins Radio Company comes KINEPLEX —
spectrum conserving, high-capacity, synchronous
ta system which transmits and receives 3,000
s of information per second on a 3 kc band,
th superior signal-to-noise performance.

daptable to wireline, cable, radio, or microwave
cilities, KINEPLEX provides twice as many
annels on a 3 kc band as present day carrier
etypewriter systems. In teletypewriter applica-
ns this means 40 channels on a 3 kc band
60, 75, or 100 words a minute operation.

INEPLEX will take stored business machine
ta in serial or parallel form and transmit it at the
me 3,000 bit per second rate. Material can be
d from magnetic tape, paper tape, punched
rds, or other storage media.

INEPLEX can also be used for telemetering,
pervisory control, and facsimile. The total data
ansmission capacity of the system can be
vided between various services to fit specific
plications. Write today for literature on
llins new TE-202 KINEPLEX Data System.



DATA

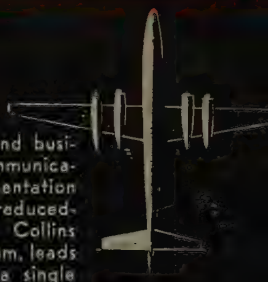
3,000 bits per second
or 40 teletypewriter channels
of 100 words per minute in
a 3 kc bandwidth, or a
combination of the two.

COLLINS

For additional information: call your nearest Collins sales office or write for technical brochure.

Collins also leads development in the fields of

AVIATION



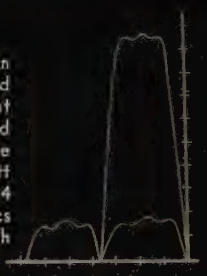
Collins completely outfits airline, military and business aircraft with the most advanced communication, navigation, flight control and instrumentation systems in aviation. Many new lightweight, reduced-size versions are now being delivered. Collins designed the original Integrated Flight System, leads in combining comm/nav/ident units into a single compact "CNI" package for new military aircraft, and continues to pace the industry in developments in airborne radar, ADF, ILS, VOR, HF and VHF communication.

GROUND COMMUNICATION



Collins engineers, designs and supplies the equipment, installs, and puts into operation integrated point-to-point communication systems of any scope. The Collins system engineering staff is backed by the finest equipment in the world, whether standard MF, HF or VHF, Transhorizon "scatter," microwave relay and multiplex or single sideband HF. Typical of Collins communication progress is "Kineplex" — a high speed data transmission system doubling communication capacity.

AMATEUR RADIO



In the early 1930's Collins set the standard in Amateur radio and, through continuous design and development, has raised this standard to its present single sideband station — the most honored and prized in the Amateur fraternity. This station is the top performing rig on the air with its kilowatt KWS-1 transmitter and highly selective 75A-4 receiver. Many of the leaders in the electronics industry became acquainted with Collins through the Company's superior Amateur equipment.

BROADCAST



Collins supplies a complete new AM station from mike to antenna or modernizes existing facilities. Besides the superior line of transmitters, Collins supplies the broadcaster's needs with such advanced additions as TV-STL microwave relay system, the lightest 4-channel remote amplifier on the market, phasing equipment and audio consoles. Collins field service organization has built an enviable reputation in assisting the broadcaster in installation or in times of emergency.

COMPONENTS AND TEST EQUIPMENT



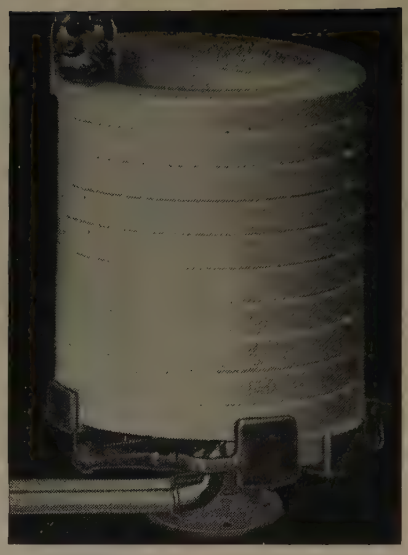
The degree of precision and reliability of Collins products requires development by Collins engineering of components such as Autotunes and Autopositioners, Mechanical Filters, oscillators, heat reducing tube shields and ferrites. These developments and other high quality components are sold by a Collins subsidiary, Communication Accessories Company of Hickman Mills, Missouri. The same principles of accuracy and reliability apply to Collins test equipment, built especially for Collins but adaptable to testing other equipment types.

LAPP INSULATION

FOR

WATER-COOLED

SYSTEMS



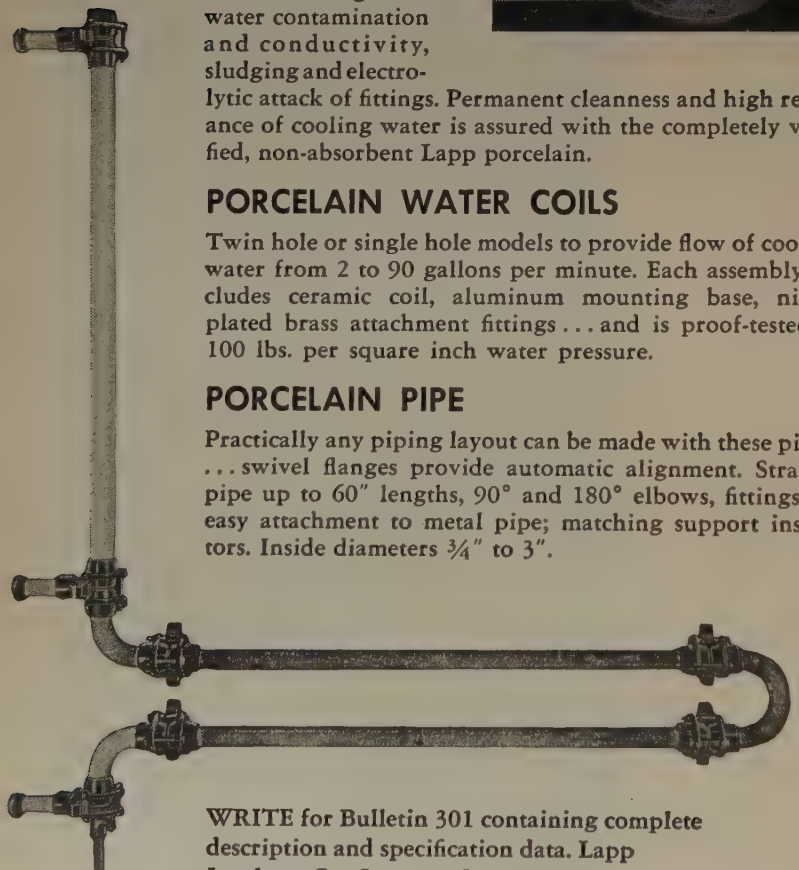
For carrying cooling water which must undergo a change in potential, use of Lapp porcelain eliminates trouble arising from water contamination and conductivity, sludging and electrolytic attack of fittings. Permanent cleanness and high resistance of cooling water is assured with the completely vitrified, non-absorbent Lapp porcelain.

PORCELAIN WATER COILS

Twin hole or single hole models to provide flow of cooling water from 2 to 90 gallons per minute. Each assembly includes ceramic coil, aluminum mounting base, nickel plated brass attachment fittings . . . and is proof-tested to 100 lbs. per square inch water pressure.

PORCELAIN PIPE

Practically any piping layout can be made with these pieces . . . swivel flanges provide automatic alignment. Straight pipe up to 60" lengths, 90° and 180° elbows, fittings for easy attachment to metal pipe; matching support insulators. Inside diameters ¾" to 3".



WRITE for Bulletin 301 containing complete description and specification data. Lapp Insulator Co., Inc., 932 Sumner Street, Le Roy, New York.

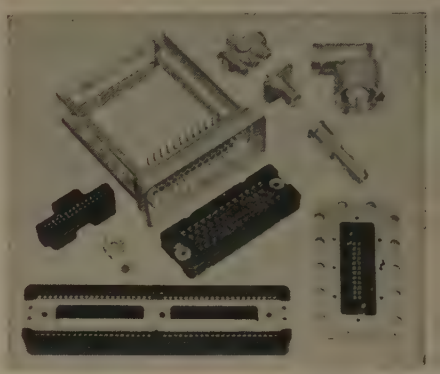
Lapp

Whom and What to See at the Radio Engineering Show

(Continued from page 122A)

Amphenol Electronics Corp.
1830 South 54th Ave., Chicago 50, Ill.
Booths 2321-2327

Arthur J. Schmitt, William H. Rous, Rodolfo M. Soria, Richard E. Hall, Charles F. Mikl, Ben Boldt, Roy J. Gallagher, Richard P. Thornton, Frank J. Novak, Charles F. Valach, Lee Allen, Carl E. Palmer, Herb Motz, Bert Jansson, Stephen R. Kelleher, Glenn E. Omholt, W. Jones, R. Klenert



Custom engineered components for electronics; standard AN, RF and Rack and Panel connectors; Subminiature components; Teflon and Polyethylene Coaxial cable; Hermetic seal headers and connectors.

Analogue Controls, Inc., Booth 3822
39 Roselle St.
Mineola, New York
W. E. Fischer
Precision potentiometers & associated equipment.

Anchor Metal Co., Inc., Booth 4521
966 Meeker Ave.
Brooklyn 22, N. Y.
Sol Lowe, Herbert Drapkin, Ben Feingold, Edwin Kent
Semiconductor Microforms—available made out of ultra pure elements or doped alloys in preformed rings, pellets, squares, cubes, discs, etc., or to individual requirements. Lead, tin, gold, indium, silver, etc.

Andrew Corporation
363 East 75th Street
Chicago 19, Illinois
Booths 1409, 1411
▲ Dr. V. J. Andrew, ▲ Robert P. Lamons, ▲ C. Russell Cox, ▲ John S. Brown, ▲ Robert C. Bicker, ▲ Charles R. Lane
Directional Gain antennas for 450-470-mc unique design provides highest gain in direction where need is greatest. Ideal base stations not in center of coverage area and where greater coverage is needed in problem direction.

Anti-Corrosive Metal Products Co., Inc., Booth 4226
River Road
Castleton on Hudson, New York
T. Gengarelly
Stainless steel & nylon fastenings.

(Continued on page 128A)

Lecture Halls in the Coliseum are located on the Fourth Floor. Take the express elevators at the front of the lobby.

not just "new" but a new KIND of OSCILLOSCOPE



-hp- 130A Low Frequency Oscilloscope

High sensitivity, dc to 300 KC

21 direct reading sweep times

Sweeps 1 μsec/cm to 15 sec/cm

Easy to use

"Universal" automatic triggering

5% voltmeter, millivoltmeter

This totally new production and laboratory instrument obsoletes previous concepts of oscilloscope convenience, usefulness and reliability.

Horizontal and vertical amplifiers are similar. Sensitivity is 1 mv/cm or 10 mv full scale deflection. Amplifiers have wide pass bands, dc to 300 KC. Input circuits are balanced on 5 most sensitive ranges. Single-ended input may be dc or ac coupled. Amplifiers are stable; gain may be standardized by an internal 1,000 cycle square wave. Sweep times are highly linear, may be set and read directly. In most cases *-hp-* 130A needs no preamplification to present transducer signals as a brilliant, high resolution trace.

A special feature is the "universal" automatic triggering system where one preset condition provides optimum triggering on almost all input signals.

Brief Specifications

Input Amplifiers: (Similar Vert. and Horiz. Amps.). Sensitivity 1 mv/cm to 50 v/cm; 14 calibrated ranges, 1-2-5-10 sequence plus continuous vernier. Pass band dc to 300 KC; ac or dc coupling. Balanced input on 1, 2, 5, 10 and 20 mv/cm ranges.

Sweep Range: 1 μsec/cm to 15 sec/cm. 21 sweeps: 1-2-5-10 sequence, 5% accuracy.

Triggering: Internal, line voltage or external 0.5 v or more. Pos. or neg. slope, +30 to −30 v trigger range.

Preset Trigger: Optimum setting for automatic stable triggering.

Amplitude Calibration: 1 KC square wave. 5% accuracy.

Price: $650.00

For the complete story on a really new oscilloscope, call your -hp- representative, or write direct.

HEWLETT-PACKARD COMPANY

4054D Page Mill Road • Palo Alto, California, U.S.A.

Cable "HEWPACK" • DAvenport 5-4451

Field engineers in all principal areas

also offers *-hp-* 150A High Frequency Oscilloscope, dc to 10 MC, sweeps 0.02 μsec/cm to 15 sec/cm. Rise time 0.035 μsec.

BOOK-OF-THE-YEAR

for

TRANSFORMER BUYERS...



NEW TRIAD

GENERAL CATALOG TR-57

Lists the complete line of transformers that have made TRIAD the symbol of quality. Includes over 75 new items. Now available from your distributor or write...

TRIAD TRANSFORMER CORP.

4055 REDWOOD AVENUE, VENICE, CALIFORNIA

812 EAST STATE STREET, HUNTINGTON, INDIANA

A SUBSIDIARY OF LITTON INDUSTRIES

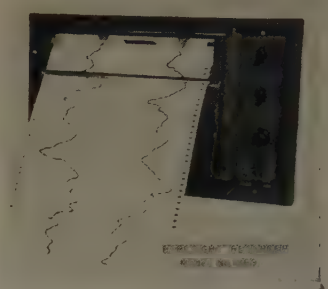
Whom and What to See at the Radio Engineering Show

(Continued from page 126A)

Antlab, Inc.
4950 North High Street, Columbus 14, Ohio

Booth 1324

Morris M. Robison, Hugo R. Fulmer, Matthew Brilliant, Marvin V. Clark, Ralph L. Sorensen, Donald W. McMahill



Boresight Recorder Model No. 1869

Antenna Pattern Range Instrumentation; emphasis on Logarithmic X-Y Recorder, Boresight Recorder, Polar Recorder, and Model Support Systems. *Pattern Integrator & X-Y Recorder.

Apex Machine Company
14-13 118th St., College Point 56, N.Y.

Booth 4606

Oliver Bodor



Apex Feed-O-Matic Print Wizard model S-302

Marking Machines for Decorating, Color Coding, Identifying or Trade-Marking all shapes and sizes of Products—Offset Machines, Direct Rubber Stamp Printing Equipment, Hot Stamping Presses.

Applied Electronics Corp., Booth 3023
1117 Commonwealth Ave. Boston 34, Mass.

▲ George H. Wayne, George F. George, Richard H. Geis, A. L. Mitchell

Shaft Position Encoder. Direct Reading Photoelectric Analog-Digital Converter offers 13 Digit Accuracy in a Transistorized Unit that is designed to meet Extremes of MIL-E-4158A.

Arco Electronics, Inc.
64 White St., New York 13, N.Y.

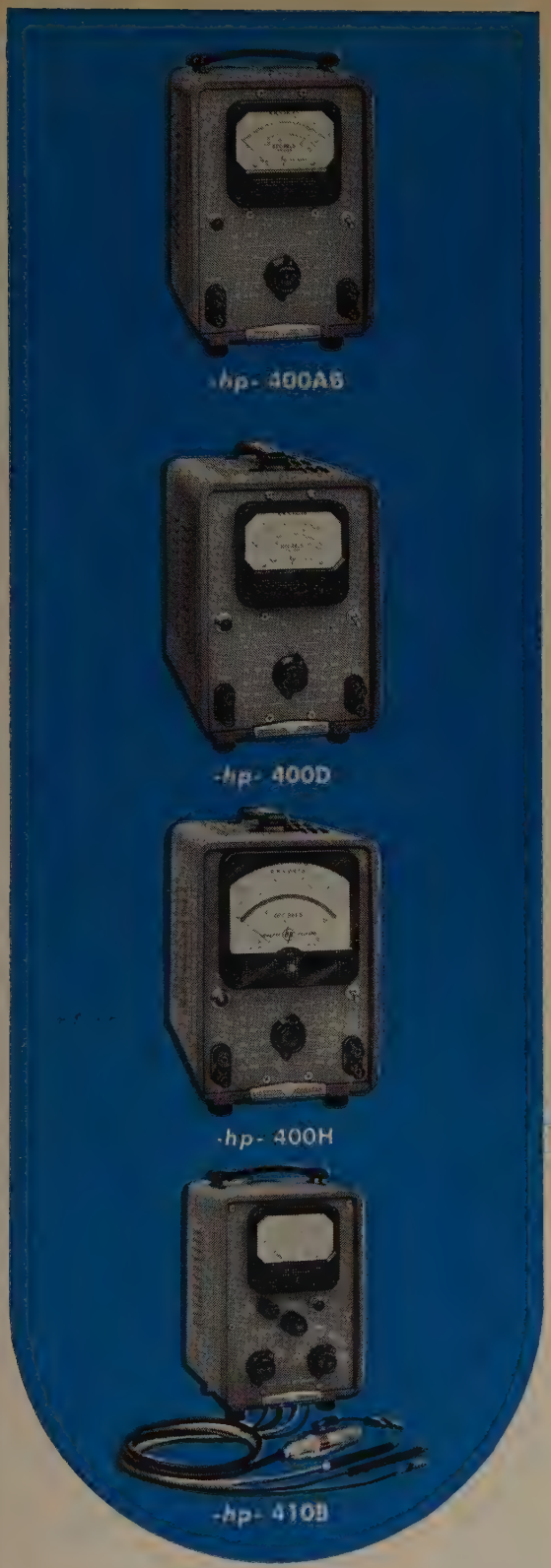
Booth 2738

▲ E. M. Rothenstein, H. L. Rothenstein, Fred Modlin, Elaine Isaacs, Hy Fox

The Revolutionary Elmenco Dur-Mica Capacitor line has been expanded with greater capacity and voltage ranges. In mica and paper dielectric, it's ELMENCO, the world's finest capacitors.

(Continued on page 130A)

find the instrument you need here



VOLTMETERS

complete coverage 10 cps to 700 MC

There is one best voltmeter for every measuring application, and -hp- has it. You can select exactly the instrument you need — the popular, multi-purpose 400AB, the wide range 400D, extreme accuracy 400H, the famous 410B which has become industry's standard for vhf-uhf measurements.

In each you find recognized -hp- accuracy, dependability, operating ease and rugged, quality construction. Each features high input impedance to prevent disturbance to circuits under test, plus high stability, good overload protection, clean, straightforward physical arrangement, new lightweight cabinetry.

In short, with every -hp- voltmeter you receive outstanding value and convenience, at moderate price.

For complete details, call your -hp- representative or write direct.

Instrument	Primary Uses	Frequency Range	Voltage Range	Input Impedance	Price
-hp- 400AB	General purpose ac measurements	10 cps to 600 KC	0.3 mv to 300 v 11 ranges	10 megohms 15 $\mu\mu$f shunt	$200.00
-hp- 400D	Wide range ac measurements High sensitivity	10 cps to 4 MC	0.1 mv to 300 v 12 ranges	10 megohms 15 $\mu\mu$f shunt	225.00
-hp- 400H	Extreme accuracy measurements	10 cps to 4 MC	0.1 mv to 300 v 12 ranges	10 megohms 15 $\mu\mu$f shunt	325.00
-hp- 410B	Audio, rf, VHF measurements; dc voltages; resistances	20 cps to 700 MC	0.1 to 300 v 7 ranges	10 megohms 1.5 $\mu\mu$f shunt	245.00

-hp- Voltmeter Accessories (not listed) include voltage dividers, connectors, shunts and multipliers to extend the useful range of your equipment.

HEWLETT-PACKARD COMPANY

4057D Page Mill Road • Palo Alto, California, U.S.A.
Cable "HEWPACK" • DAvenport 5-4451

Field engineers in all principal areas

unmatched value in vacuum tube voltmeters



Indicating Meter is standard for all models in High Power Rigid Line Series.

Thruline Directional Wattmeter

for

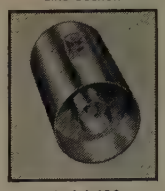
HIGH POWER RIGID LINES

A most accurate instrument for measuring and/or constantly monitoring forward and reflected power in rigid 50 or 51.5 ohm transmission lines. In addition, it may be used as the detecting element of transmission alarm systems; for measuring power being dissipated by a compatible load resistor, and; for remote reading of forward and reflected power by using line section with provisions for inserting two directional couplers in the same cross-sectional plane.

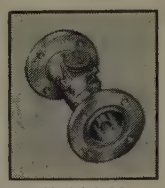
Visit us at the IRE Show — Booth #3215 and #3217.



Model 460
3-1/8"
Line Section



Model 490
6-1/8"
Line Section



Model 4712
1-5/8"
Line Section



Model 480
3-1/8"
Line Section

Complete specifications are available in Bird's New Bulletin #406.

BIRD ELECTRONIC CORP.
EXpress 1-3535
1800 E. 38 St., Cleveland 14, Ohio
Western Representative: VAN GROSS COMPANY • Sherman Oaks, California

DEE PRINTED CIRCUIT SOLDER POTS
WITH MECHANICAL TYPE DIAL THERMOMETERS



All components except the elements may be serviced easily without taking the pot apart. High-low heat switch so that pot may be used for hand dipping or fast machine dipping without excessive cycling.

IRE SHOW BOOTH NO. 4043

New proven design with all controls on end of pot. Mechanical type dial thermometers to indicate solder temperature. Hydraulic thermostats. Walls and bottom of the solder cavities are smooth and free of all obstructions. 25 sizes meet all requirements.

Send for bulletin.

DEE ELECTRIC CO.
1111 N. Paulina St., Chicago 22, Ill.



The Rixon • MUX-16
(AN/TCC-35)

Booth 1725 **IRE Show**

A sixteen channel TTY time division system utilizing computer components and new packaging techniques. Developed by Rixon for MIT, Lincoln Laboratory, and the United States Air Force.

RIXON ELECTRONICS, INC.
2414 Reedie Dr. Silver Spring, Md.

Whom and What to See at the Radio Engineering Show

(Continued from page 128A)

Aries Laboratories, Inc., Booth 4117
45-33 Davis St.
Long Island City 1, N. Y.
Harry Isbenjian, Bill Stern, Murray Goldfinger
High heat resistant resins. Complete line of encapsulating, impregnating and coating resins and adhesives. Satisfy class H requirements. Exhibit of various types of equipment utilizing airtemp resins.

Arma Division, American Bosch Arma Corporation
Roosevelt Field, Garden City
L. I., New York
Booth 1713
F. H. Guterman
Design, Development, Inertial Guidance Systems.

Arnold Engineering Co.
P. O. Box G, Marengo, Ill.
Booths 2201-2205
▲ Robert M. Arnold, H. H. Friend, ▲ C. S. Brand, J. E. Mitch, ▲ Benjamin Falk, A. C. Brown, J. R. Hansen.
MAGNETIC CORES
ALNICO PERMANENT MAGNETS
IRON POWDER CORER
MAGNETIC MATERIALS

Artos Engineering Co., Booth 4228
2757 South 28th St.
Milwaukee 46, Wis.
Haakin T. Randar, Anders Moline, Henry Meyerson, Casmir Terry
CS-6 Machine. *Device for marking wire leads. *Knock-outs for stripping scrap. *Wire prefeeder. *Collecting devices.

Assembly Products, Inc., Booths 3916-3918
Wilson Mills Road
Chesterland, Ohio
▲ Bradley Thompson, ▲ John D. Saint-Amour, ▲ Robert H. Pugsley, ▲ Lloyd Rowe, ▲ Saul Cohen, George Z. Griswold
Three-position interlocking control circuit, correcting signal to a specific point, will be among several new controls to be exhibited, incorporating company's contact meter-relays.

Associated American Trading Division, Booths 4109-4111
750 St. Anns Ave.
New York 56, N.Y.
G. B. Franklin, L. I. Guttman, ▲ George Embree, Irwin Wolf, Pat Rodrigues, Walter Forster, Betty Martens
Upside-down Coil Winding Machine enabling the precision winding of instrument coils with very fine wire in a way never before possible.

Associated Missile Products Corp. (sub. of American Mach. & Foundry), Booth 1522
2709 North Garey Avenue
Pomona, California
E. R. Skaggs
Guided missiles & ground support equipment.

(Continued on page 132A)

Be sure to see all four floors!

New Driver Chain for Pulsed High-Power Radar





Sperry's New Metal Traveling Wave Amplifiers Cover 1100-1600 mc Range in L-Band

NOW IN PRODUCTION, these Sperry high-power traveling wave amplifiers bring new flexibility to pulsed high-power radar systems, and offer special advantages as wide-band repeaters and swept frequency amplifiers.

AS THE DRIVING POWER for multi-megawatt klystrons, the STL-111 and STL-114 feature a high duty cycle and fast—even instantaneous—frequency change *with no need for tuning or voltage modification*. In cascade they amplify a signal from 2 mw to 7 kw, with a gain of over 60 db.

RESISTANCE to thermal and mechanical shock is extremely high, due to sturdy metal envelope and ceramic rods supporting the helix. RF connectors are integral parts of the tube structure.

Write our Electronic Tube Division for data sheets on these new amplifiers (as well as other driver chains in other high frequencies).

CHARACTERISTICS:	STL-111	STL-114
Frequency Range	1100-1600 mc	1100-1600 mc
Saturation Power Output	4w	7kw
Gain at Saturation Power	30 db	34 db
Small Signal Gain	36 db	40 db
Beam Voltage	900 v	14 kv
Duty Cycle	Continuous	.005
Magnetic Field	450 gauss	700 gauss

ELECTRONIC TUBE DIVISION

SPERRY GYROSCOPE COMPANY

Great Neck, New York

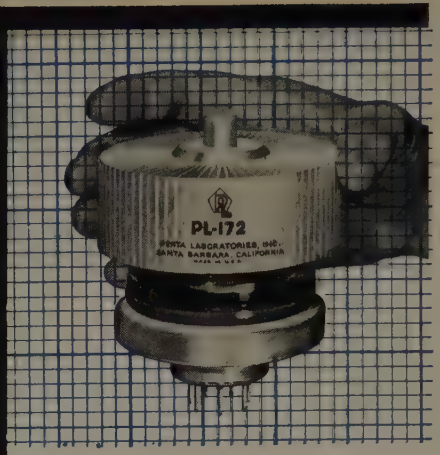
DIVISION OF SPERRY RAND CORPORATION

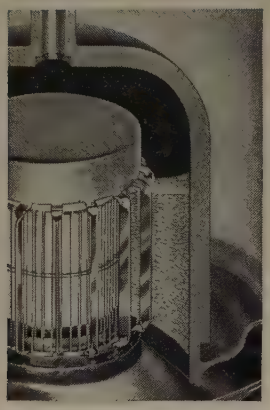
CLEVELAND • NEW ORLEANS • BROOKLYN • LOS ANGELES • SAN FRANCISCO • SEATTLE
IN CANADA: SPERRY GYROSCOPE COMPANY OF CANADA, LIMITED, MONTREAL, QUEBEC

VISIT SPERRY AT THE RADIO ENGINEERING SHOW, NEW YORK COLISEUM, MARCH 18-21, BOOTHS 1416-1422

versatile new
PENTA PL-172
external anode
1-KW BEAM POWER PENTODE

new design principle
gives extra-high power
at low plate voltages





This new pace setter delivers high power at low plate voltage for a variety of r-f and a-f applications. The exceptional performance of the PL-172 is due to the exclusive new suppressor grid vanes which direct electrons to the plate in beams, giving true beam tube characteristics. For critical Class AB_1 linear amplifier applications, for high power audio service, or for high-efficiency, low-drive Class-C use, the PL-172 is a logical choice.

USE IT AS A CLASS-AB_1 LINEAR R-F AMPLIFIER—

Delivers over 1000 watts useful output at only 2000 plate volts, over 1500 watts at maximum ratings.

AS A CLASS-C AMPLIFIER—

Over 2000 watts useful output at high efficiency. Driving power less than 5 watts.

OR AS A CLASS AB_1 AUDIO AMPLIFIER—

Over 1200 watts per pair at 1500 volts. Up to 3000 watts at maximum ratings. Low output impedance simplifies output transformer problems.

RATINGS

Heater Voltage.....6.0 volts	Plate current, max.....1.0 amperes
Heater Current.....7.5 amperes	Plate dissipation, max. ....1000 watts
Plate voltage, max.....3000 volts	Transconductance .....21,000 μmhos

A COMPLETE LINE OF HIGH-EFFICIENCY POWER TUBES

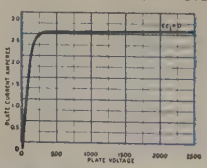


Plate current curve at zero grid voltage shows why the PL-172 gives high power gain and operates efficiently at low voltages.

Write for complete technical data and suggested operating conditions.

Representatives in principal cities.

PENTA *laboratories, inc.*
316 N. Nopal St., Santa Barbara, Calif.

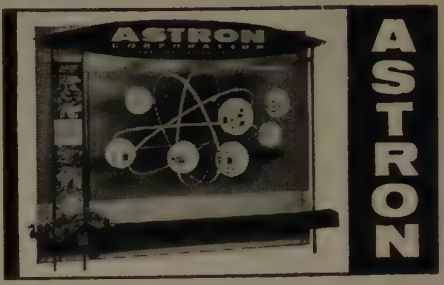
VISIT OUR BOOTH #2740 AT THE IRE SHOW

Whom and What to See at the Radio Engineering Show

(Continued from page 130A)

Astron Corp.
255 Grant Ave., East Newark, N.J.
Booth 2927

P. M. Maier



Capacitors, filters

Atlas E-E Corporation, Booth 4235
47 Prospect St.
Woburn, Mass.

▲ Allan Q. Mowatt, Newton Myers

*Tab-Mounted Component Clips; *Transistor Clips & Heat Sinks; *G. E. 6By4 Tube Clip; Jan Shield Inserts and clips for all types of electronic components.

Audio Devices, Inc., Booth 2720
444 Madison Avenue,
New York 22, N. Y.

Bryce Haynes, Herman Kornbrodt, Rod L. Hickey, Frank Radocy, G. R. Freifeld, G. S. Johnson

Type EP Audiotape—new and improved magnetic recording tape for all instrumentation uses. The complete line of Audiotape for every recording need. Audiodiscs, Audiofilm, Audiopoints.

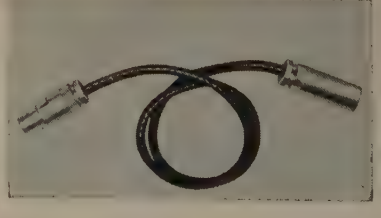
Automatic Electric Sales Corp.
1033 W. Van Buren St.,
Chicago 7, Ill.
Booth 1906-1908

H. C. Smith, H. S. Williams, V. E. James, J. D. Ashby, H. P. Hohberger, A. T. Brennan, R. Winthrop, Alan Grady, G. Downs, L. Mitchell, L. A. Eisenstein, A. A. Gandolph, J. F. Harm

*Relays for printed circuits. Relays and switches, telephone type, for Communications and Industry, By the company Originating Dial Telephony.

Automatic Metal Products Corp.
315-323 Berry, St., Brooklyn 11, N. Y.
Booth 4426

Marc W. Martin



Sub-minature push on connector

Coaxial connectors, fittings, switches, relays.

(Continued on page 134A)

* Indicates new product.
▲ Indicates IRE member.

How to use a Wave Analyzer on an Ocean Wave

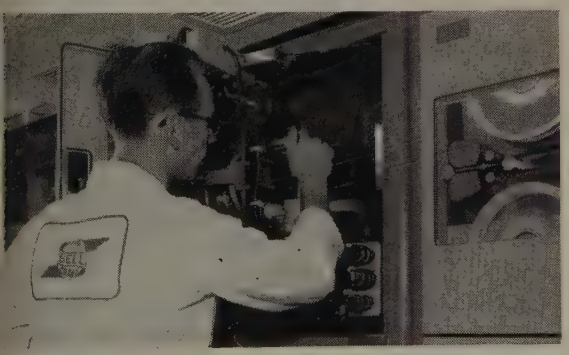
(or any low frequencies from 1/10th to 5 cycles per second)

A head-on attack on this problem will soon uncover the disconcerting fact that wave analyzers just don't come this big. Those of a more comfortable size generally operate on frequencies of five cycles per second and more.

But frequencies as low as 1/10th cycle per second — like earthquake waves, ship motion, and low-frequency vibrations of large machines and structures can be fed to conventional wave analyzers with completely satisfactory results. Magnetic tape recording provides an essential conversion step between.



Bell Aircraft Corporation's magnetic-recorder installation aboard the SS Mariposa for study of ship motion.



Speed change on the Ampex FR-100 is accomplished quickly and easily by a selector knob and switch.

Two Ampex FR-100 magnetic recorders were purchased and installed aboard the SS Mariposa for Bell Aircraft Corporation's study of ship motion at sea. The frequencies encountered were far below one cycle per second. These were recorded at the lowest tape speed on the recorder (1⅞ in/sec.). Reproducing the tape at the highest tape speed (60 in/sec.) multiplied the frequencies by 32. Recopying onto the second recorder and speeding up again increased the total speedup to 32 x 32 or a total of 1024. As an example, a frequency of 1/10th cycle per second became approximately 100 cycles per second and was easily separated and measured by wave-analysis equipment.

The Ampex FR-100 recorder has six standard speeds from 1⅞ to 60 in/sec. in the ratio of 1, 2, 4, 8, 16 and 32. Recopying accomplishes further multiplication by powers of two. Even a second recopying is perfectly feasible just in case you are interested in a frequency multiplication of 32,768.

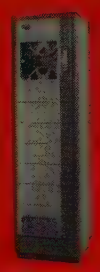
Putting low frequencies onto magnetic tape requires an FM-carrier recording. On the Ampex FR-100 this is conveniently provided by plug-in amplifiers. Frequency response at 1⅞ in/sec. tape speed is 0 to 312 cycles/sec. At 60 in/sec. it is 0 to 20,000 cycles/sec. Besides its ability to record very low frequencies, FM carrier recording has the very desirable attribute of high instantaneous amplitude accuracy. Thus, the reproduced waves retain their original form very accurately through any amount of speedup.

If you have a problem that might be solved by data speedup, we would be pleased to furnish further information. Others of magnetic tape's remarkable capabilities will be the subjects of a continuing series of these bulletins. Would you like copies mailed direct? Write Dept. G-3134

MAGNETIC TAPE APPLICATIONS BY AMPEX

1

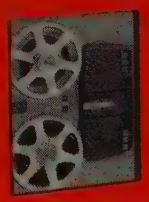
ONE OF A SERIES



Series FR-100



Series 800 Mobile and Airborne



Model FR-200 Digital



Tape Loop Recorder



Series FR-1700

INSTRUMENTATION DIVISION

AMPEX CORPORATION

FIRST IN MAGNETIC TAPE INSTRUMENTATION

934 Charter Street • Redwood City, California

District offices serving all areas of the United States and Canada; Foreign Representatives in countries around the world.

Gives you direct capacitance reading from 0.01 μμf to 12 μf



BALLANTINE CAPACITANCE METER Model 520

1932 1957 25TH Anniversary

The Model 520 Capacitance Meter is a general laboratory instrument which measures capacitance over the wide range found in paper, plastic, mica, ceramic and air type capacitors. The value of unknown capacitance is read directly from the meter scale by manipulating only one control knob. The ability to measure direct capacitance, excluding strays, makes it very useful for low value measurements. Adjustable limit pointers, together with fast operation, make it valuable for incoming inspection departments. The instrument has a built-in calibration standard.

SPECIFICATIONS

RANGE:	0.01 μμf to 12 μf	FREQUENCY:	1,000 cps
ACCURACY:	2%, 0.1 μμf to 12 μf; 5%, 0.01 μμf to 0.1 μμf	METER:	Logarithmic scale
		SIZE:	13½" x 7½" x 7"

BALLANTINE LABORATORIES, INC.

102 Fanny Road, Boonton, New Jersey

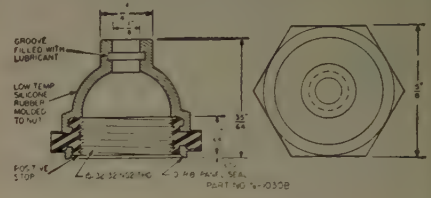
Whom and What to See at the Radio Engineering Show

(Continued from page 132A)

Automatic & Precision Mfg. Co.
252 Hawthorne Avenue, Yonkers 5, N.Y.

Booth 3824

▲ Milton Morse, ▲ Riva Solins, Nat Kronstadt, ▲ Robert Smith, Adolph Friedman, David Friedman, George Antonian



New Rigid Hexnut

"Military-Approved Watertight Switch and Shaft Seals"; also high-pressure self-sealing screws and bolts. Power connectors in accordance with military specifications

AVCO Crosley Division
Research and Advanced Development Div., Cincinnati 15, Ohio

Booth 1627

▲ D. Nason, ▲ P. Smith, ▲ G. Mansur

Avcom-walkie-talkie communication for business and industry. Volscan-air traffic control system.

Axel Brothers, Inc.
Electronics Division
134-20 Jamaica Ave., Jamaica 18, N.Y.

Booth 1511

▲ J. P. O'Donnell, C. B. Axel, M. J. Del Grosso, R. H. Elkes, M. Matnick, C. B. Bitettie



Low Inductance Capacitor

Manufacturers of Low Inductance Capacitors, Filters, Pulse Network, Special Capacitor and Precision Wire Wound Resistors.

The B.G. Corporation, Booth 4037
321 Broad Avenue
Ridgefield, N.J.

R. W. Brattvet, M. A. Murray, R. G. Ames, G. J. Waiver, V. F. Procopio

High Temperature Ceramic-Metal Seals
Alumina Ceramics
Hermetic Seal Terminals and Bushings.

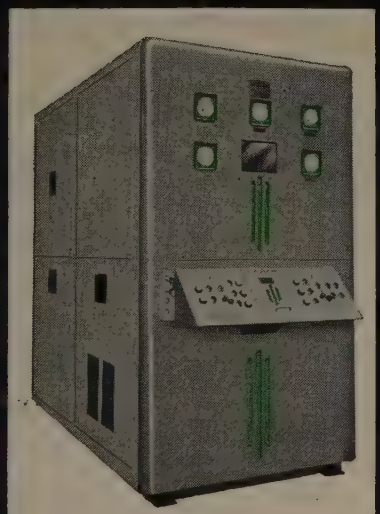
(Continued on page 136A)

Take the elevators at the front of the lobby to go direct to the fourth floor.

tomorrow is here today!

Rising like a copter, this tilt-wing transport will cruise at 350 m.p.h. Originally thought of as an impossibility, this unusual plane is in the design stage today. The versatility of flight direction is accomplished by tilting the wings 90 degrees for vertical takeoffs and landings. Tilting with the wing are four six-blade, contrarotating propellors and their high powered turboprop engines. Today's airports with their extensive runways may soon be facing obsolescense.





Z821A

CUSTOM MODULATORS from STANDARD DESIGNS

FXR High-Power Pulse Modulators are custom-built to meet the specific requirements of each application through the use of FXR standard designs, developed by our skilled modulator engineering group. Our staff of experienced application engineers cannot be surpassed in the close integration of the most recent engineering developments with packaged design and standard procedures. You benefit, with a precision instrument of economical cost.

FXR's competent and efficient research, design and development staff, augmented by ultra-modern manufacturing facilities capable of production-quantity fabrication welcomes the opportunity to aid you in the design and construction of the most intricate pulse modulators and high-voltage power supplies.

Send for the "Preliminary Questionnaire" to assist you in planning the design of your next High-Power Pulse Modulator!

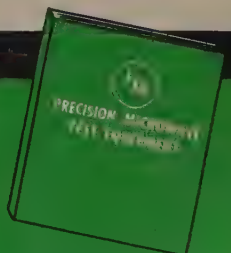
High Power Modulator Type No.	Power (peak mega-watts)	Voltage (peak kilovolts)	Current (peak plate-amperes)	Impedance (output-ohms)	Duty Cycle (maximum)	Pulse Shape (μsec/pps)	Input 60 CPS (Ø/volts)	Size (HxWxD, ft.)	Weight (lbs.)	Tubes Operated
Z820A	1.0	33	33	1,000	.001	0.5/2000 2.5/400	1/190-250	6x2x3	1400	4J50, QK-349 RK-6249
Z821A	14.0	90	160	560	.001	2.0/200-500	3/440-550	7x4x7	6800	QK-338
Z822A	0.2	20	10	3,330	.018	10/1200- 1800	3/440	6x3x4	3330	SAL 39 (GL-6625)
Z823A	0.042	12.7	3.3	3,330	.064	coded/300	3/440	6x4x4	3200	SAL 39
Z824A	0.625	25	25	1,000	.001 at 0.5/2000	1.0/1000 2.0/250 5.0/100	1/190-250	6x2x3	2500	QK-349 at reduced power
Z825A	1.6	40	40	1,000	.001 at 0.5/2000	1.0/1000 2.5/400	1/190-250	6x2x3	2500	WE-5780

Modulator Loads and Exhaust Ovens are also available.

See us at the IRE Show BOOTH 3715, 3717

FXR · ELECTRONICS & X-RAY DIVISION · F-R MACHINE WORKS, INC.





Electronics & X-Ray Division

F-R MACHINE WORKS, Inc.

26-12 Borough Place, Woodside 77, N. Y. AStoria 8-2800

Write TODAY for new catalog of complete line of Precision Microwave Test Equipment.

Representatives: Los Angeles: J. C. VanGroos Co.; Denver: Hytronic Measurements Inc.; Chicago: KaDell Sales Assoc.; Export: Szucs Int'l Co., N. Y.

ridiculous!

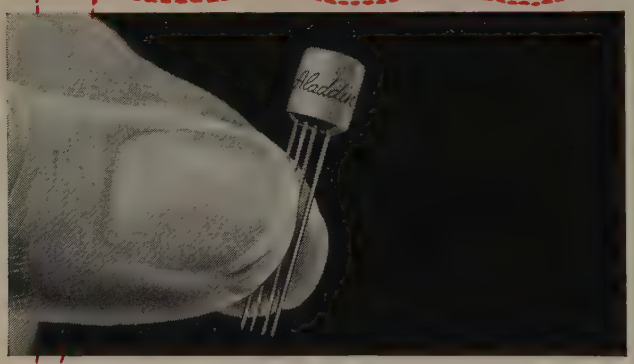
you can't mix magic and

Pulse Transformers



but, sir... you're wrong!
just look at this new

micro-miniature



- Diameter .265 inch
- Primary inductances as great as 50 millihenries
- Rise times as short as .02 microseconds
- Designed to meet MIL-T-27A environmental specs.
- Leads brought out one or both ends

THAT NEW IDEA

Designed for transistor blocking oscillator circuits and other applications requiring the utmost in space economy . . . this new Aladdin line has been added to the other standard types described in our Pulse Transformer Encyclopedia for Circuit Designers.

Write on company letterhead for technical information.



Aladdin ELECTRONICS

A Division of Aladdin Industries, Inc.
719 Murfreesboro Road, Nashville 2, Tenn.
Tarrytown, N. Y.; Pasadena, Cal.

Whom and What to See at the Radio Engineering Show

(Continued from page 134A)

B. J. Electronics Div
Borg-Warner Corp.
3300 Newport Ave., P.O. Box 1679, Santa Ana, Calif.
Booth 3506

Grant Corby

In full operation—complete BJ Digital Data Reduction System with Vibrotron As Absolute Pressure Transducer-Model 75 Standard Signal Generator—Detectolab Medical Spectrometer DZ 21

Baird Associates-Atomic Instrument Co., Booths 3219, 3221
33 University Road
Cambridge 38, Mass.

S. Futran, H. Aronson, Carl Richardson, H. Gram, A. Krasnow, J. Plunkett, J. Dutton, J. Carlin, R. O'Toole, L. Mead

Exhibiting new transistor testing instruments, high-speed electronic counting devices, and radioactivity measurement systems.

Baker & Company, Inc., Booth 2106
113 Astor Street
Newark 5, New Jersey

I. Shippard, V. Burris, H. Day, T. Hartnett, Jr., C. Sivil, H. Robinson, G. R. Briechle

A complete line of contact (precious metal) materials—Rhodium Plating—Fine Wires—Deoxo Purifiers—Coolers for Electronic Power Tubes.

Balco Research Laboratories, Booth 2123
49-53 Edison Place
Newark 2, N.J.

▲ Lawrence E. Friedman, ▲ Dr. Maxwell K. Goldstein, Robert Nobel

Metallized teflon capacitors. Smaller than paper capacitors yet operate from —70°C to 200° without derating. Insulation Resistance of 10^{21} ohms, dissipation factor 0.0005 lowest dielectric absorption. Also standard teflon capacitors: IR of 10^{14}, stability 2% over entire —70 to +200°C. Adjustable teflon capacitors: IR of 10^{14}, stability .01% (over limited temperature range).

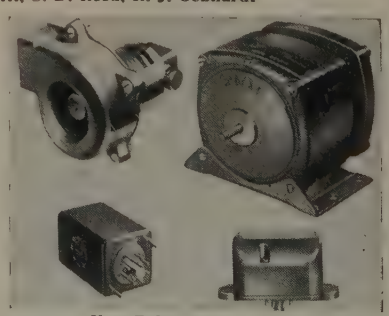
Ballantine Laboratories, Inc.
102 Fanny Rd., Boonton, N.J.
Booths 3402-3404

▲ Frank R. Zayac, ▲ Dr. Endel Ulga, ▲ Wallace F. White, ▲ Henry Kruger, ▲ Gustav Mannik, ▲ Herbert Vorwerk.

Sensitive Electric Voltmeters, True RMS Electronic Voltmeter, Very Low Frequency Voltmeter, DC-AC Precision Calibrator, Decade Amplifier, Sensitive Electronic Inverter, Capacitance Meter, DC Output Adapter, Voltage Multipliers, Shunt Resistors, etc.

Barber-Colman Company
1400 Rock Street, Rockford, Ill.
Booth 2240

W. F. Tice, R. K. Warnimont, F. D. Utter, B. L. Hiltt, S. D. Reed, R. J. Gebhardt

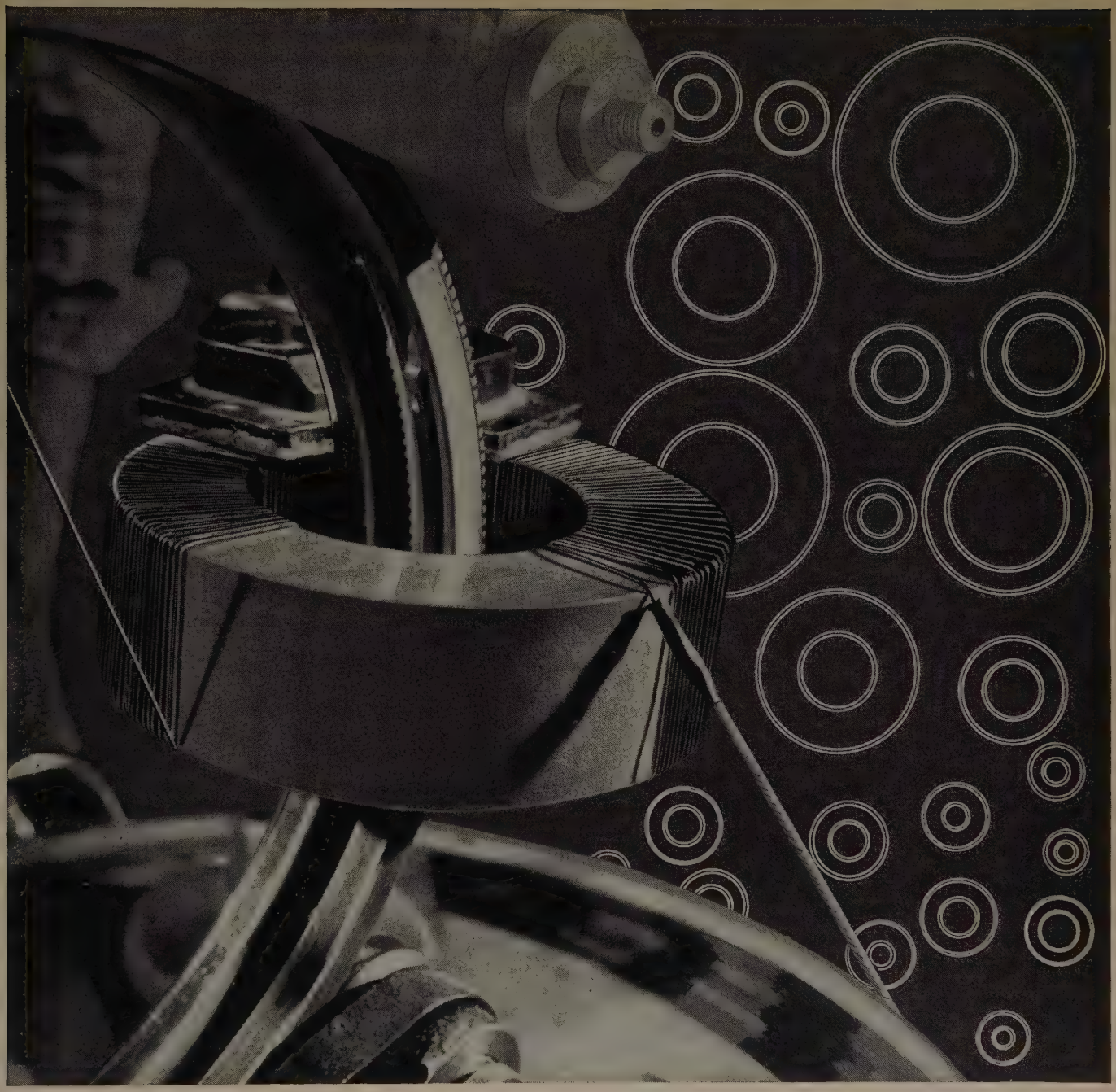


New Relays and motors.

Ultra-Sensitive Polarized D-C Relays (Null-Seeking, Magnetic Latching, Snap-Acting, and Transistorized Types); Sub-Fractional Permanent Magnet D-C motors; Shaded Pole A-C Motors

(Continued on page 138A)

KEEP UP-TO-DATE ON MAGNETICS



How will tape wound core users be affected by new size standards?

If toroidal core winding is a familiar sight in your plant, you'll welcome news that standard sizes for tape wound cores have been proposed by the A.I.E.E.* You are going to benefit from a high in consistency of core performance, brought about by our being able to concentrate on your most important sizes.

Magnetics, Inc. is now stocking all of the proposed standard core sizes in both aluminum and phenolic core boxes for immediate delivery. Consistency of core performance is increased because each size is made in large lots taken from the same alloy batch and dry hydrogen anneal. They all bear our exclusive Performance-Guarantee.

You can find all specifications for these AIEE-standardized tape wound cores in Catalog TWC-102, a new publication which, incidentally, is the most comprehensive tape wound core text published anywhere by anybody. Your copy of this Catalog-Design Manual may be obtained by writing on your letterhead to *Magnetics, Inc., Dept. I-34, Butler, Pa.*

MAGNETICS inc.

*Paper 57-206, Proposed Size Standards for Toroidal Magnetic Tape Wound Cores. Report of the Magnetic Amplifiers Material Sub-Committee, at the 1957 Winter General Meeting, A.I.E.E.



Vari-Flex®

CHASSIS and POWER SUPPLIES

. . . Save You TIME and MONEY

- Combines ready-to-assemble chassis with high quality regulated power supplies — Saves time — Construction starts where it should with the circuits proper.
- Instantly demountable construction for circuit salvage or substitution.
- Two sizes of assembly — 9" and 13½" depth, utilizing three interchangeable chassis plates 4½", 9", and 6¾" deep.
- Standard RETMA overall size for convenient rack mounting. Panel size 8¾" x 19".
- Perforated metal shields available for top and bottom.
- Regulated Power Supplies — constructed on 4½" chassis plate — have extremely low ripple and excellent regulation and transient recovery characteristics.



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Hamner Electronics Co., Inc.

P.O. Box 531, Princeton, N. J. • PEnnington 7-1320

See us at the IRE Show, Booth #3022

Whom and What to See at the Radio Engineering Show

(Continued from page 136A)

Barnes Engineering Co., Booth 3024
30 Commerce Road
Stamford, Conn.

Robert McDonald, Michael Portanova, Eric M. Wormser, Richard Leftwich, Donald Frothingham, Seymour G. Linsley

Infrared thermal photography system; fast, sensitive industrial Radiometer; infrared components—black bodies, detectors, etc.; Binotrol tape program, automatic positioning table and automatic machine tool control.

Barry Controls, Inc., Booth 2534
700 Pleasant St.
Watertown 72, Mass

E. A. Johnson, T. P. Goethel, Russ Lowe, Tom Black, Walter Fredrick, Henry Bostder, Morris Silverman

New T/Plotter charts transmissibility curve. New All-Angl mounting Systems. New Mil-spec Mount. Complete line unit mounts and mounting systems and bases.

Baso Incorporated, Formerly Milwaukee Gas Specialty Co., Booth 2709
730 No. Jackson Street
P. O. Box 461, Milwaukee 1, Wis.

William G. Fetter, ▲ Russell B. Matthews, Jerome Dietz, ▲ Peter T. Milunzi, William F. Nolden, Frank Ondrejicka, Frank R. Shibiliski

6-Pole Relay, AC Relay, Time Delay Relay, Sub-Miniature Relay, Temperature Compensated Relay.

Morris Bean & Co., Booth 3240
Yellow Springs, Ohio

G. H. Kepler, Robert Moore, G. B. Davison

Antioch Process cast aluminum wave guide components; Feed Horns, Rotating Joints; Elbows; duplexers; Pressure Windows; Transition sections; Power dividers.

Beemer Engineering Co., Booth 4119
401 N. Broad St.
Philadelphia 8, Pa.

H. G. Silcox, III

Oilite bearings & metal powder parts.

Behlman Engineering Co., Booth 3837
114 South Hollywood Way
Burbank, California

Jean Schroeder, Eugene Cahn

The Behlman Invertron—A.C. Power Source Completely Electronic—Dependable—Silent in Operation—Wide Range of Output Frequency and Power

Belden Manufacturing Co., Booth 1630
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Chicago, Ill.

Warren Stuart, R. L. Reading, Frank Timmons, John McEwen, George Kyros

BELDSOL—the BIGGEST film-coated wire development since Nyclad.

Bell Aircraft Corp.
P.O. Box 1
Buffalo, N.Y.

Booths 1328-1330

Robert R. Payne, Robert Sellers

Aeronautical and Navigational Systems and Equipment.

Belling & Lee, Ltd., Booth 2007
Gr. Cambridge Rd.
Enfield, Middlesex, England

Multi-way and coaxial plugs and sockets, fuselinks and fuse holders, terminals, binding posts, bi-metal cutouts and delay switches. Interference suppressors, screen room.

(Continued on page 140A)

* Indicates new product.
▲ Indicates IRE member.

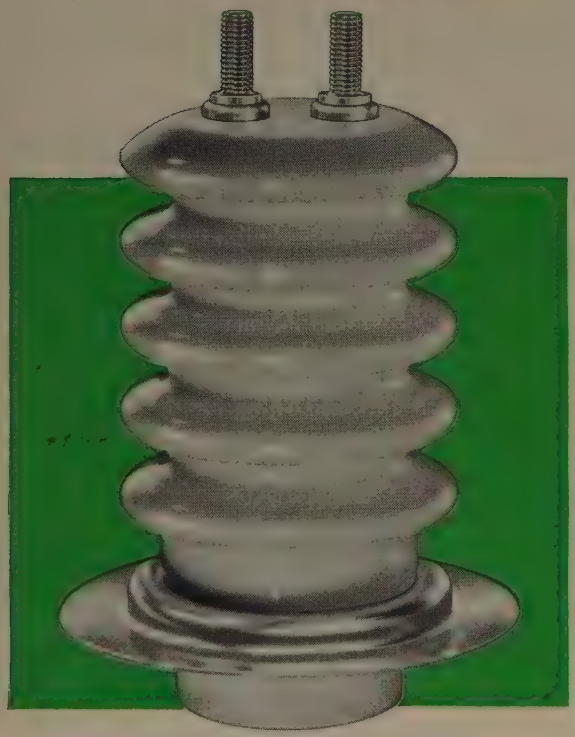
Now...



One Integrated Source

for High Temperature • Vacuum-Tight
Mass-Spectrometer Tested

Ceramic-to-Metal Seals



NOW AVAILABLE—A standard line of Alite high voltage bushings. Sizes 2" or 2¾" diameters; 2 to 8 flutes; 1, 2 or 3 terminal studs; optional stud lengths and thread sizes.

With the addition of complete facilities for high temperature metalizing and bonding, our Alite Division offers engineers and designers a single dependable source for ceramic-metal assemblies. Now you can plan for superior quality and highest precision in electronic insulating components employing ALITE—the sintered aluminum oxide especially formulated for critical electronic applications.

Alite possesses a unique combination of properties which makes it ideal for use as the insulating body in ruggedized, high performance hermetic seals and bushings. It has exceptionally high mechanical strength and thermal shock resistance, permitting operation over wide extremes of temperature, pressure, humidity and vibration. Alite maintains its high dielectric strength and excellent low-loss characteristics at micro-wave frequencies and elevated temperatures.

Alite seals are operative at extremely high temperatures, being limited only by the melting point of the bond metal used. When Alite is metalized and bonded, using high temperature brazing metals such as pure silver, copper, gold, or their alloys, the result is a vacuum-tight Alite-to-metal seal that meets the most exacting requirements.

Get in touch with us if you have component problems involving ceramic-to-metal seals.

Our technical service is ready to handle your toughest assignments.

A Few Outstanding Properties of ALITE

Tensile Strength	26,500 psi
Compressive Strength	285,000 psi
Dielectric Constant @ 10,000 mc	8.4
Dielectric Strength (volts per mil)	250
Power Factor @ 10,000 mc	0.0008
Loss Factor @ 10,000 mc	0.0067

Visit ALITE at the IRE Show—Booth 4236

ALITE DIVISION

U. S. STONEWARE

AKRON 9, OHIO

NEW YORK OFFICE: 60 EAST 42nd ST.

480-E

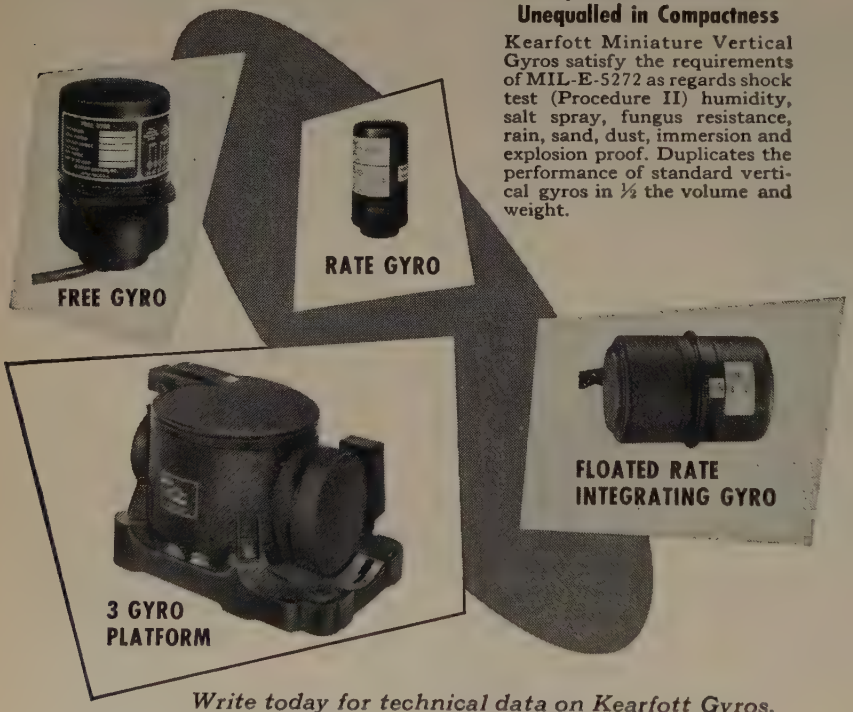
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for every application

For hours in aircraft or minutes in missiles, gyros must possess ruggedness and dependability that will assure performance of the mission. Kearfott Gyros possess this ruggedness and dependability coupled with extremely high accuracy. That is why they are so widely used in all types of aircraft and missiles. Kearfott Vertical, Rate, Free, Directional and Floated Rate Integrating Gyros as well as Stable Elements are designed to meet the most stringent airborne requirements.



Unsurpassed in Performance
Unequalled in Compactness

Kearfott Miniature Vertical Gyros satisfy the requirements of MIL-E-5272 as regards shock test (Procedure II) humidity, salt spray, fungus resistance, rain, sand, dust, immersion and explosion proof. Duplicates the performance of standard vertical gyros in ½ the volume and weight.



Write today for technical data on Kearfott Gyros.

KEARFOTT COMPONENTS INCLUDE:
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Whom and What to See at the Radio Engineering Show

(Continued from page 138A)

Bendix Aviation Corp.
Bendix Radio Div.
2120 N. Charles St.,
Baltimore 18. Md.
Booths 2322-2425

W. W. Price, ▲C. I. Rice, R. S. Finke, Charles McAtee, L. H. Jones, ▲J. W. Colvin

Cutaway of aircraft showing actual radio rack installation—highlights savings in size and weight with new designs. Display also contains very latest communications and navigation equipment.

Bendix Aviation Corp.
Eclipse-Pioneer Division,
Teterboro, N. J.
Booths 2322-2425

E. J. Petterson, J. A. Sullivan, R. W. Ramm, C. W. Baun, W. A. Hall, G. Guthrie, J. Bales, F. Thornton, T. Sprink, T. Kanell, G. Lathrop, G. E. Greenhagen.

Position induction generators, synchros, low inertia motors, motor generators, gyros, radar ordnance synchros and mechanisms from Polar Path compass coupler.

Bendix Aviation Corp.
Pacific Div.
11610 Sherman Way,
N. Hollywood, Calif.
Booths 2322-2425

R. A. Nicol, C. Ruckstuhl, A. Dow, E. W. Copeland, H. D. Wilkinson

Radar, Sonar, Telemetering and Decca Navigation System

Bendix Aviation Corp.
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J. Bozzelli, ▲J. Johnstone, ▲R. Kunnapfel, ▲J. Wyman, ▲T. Fentress, ▲R. Gormly

High temperature, High vibration tubes, Ruggedized klystrons and high current cold cathode discharge tubes. Also power supplies including missile applications.

Bendix Aviation Corp.
Scintilla Div.
Sidney, N.Y.
Booths 2322-2425

D. W. Newcomb, G. W. Conover, R. E. Rice, H. F. Gallup, F. N. Bukkem, J. C. Youmans

"Pygmy" Miniature Electrical Connectors, Bendix Electrical Connectors—Rack & Panel, Short "E", AN—other Standard & Special Types. Protected Wiring Assemblies for Environmental Protection.

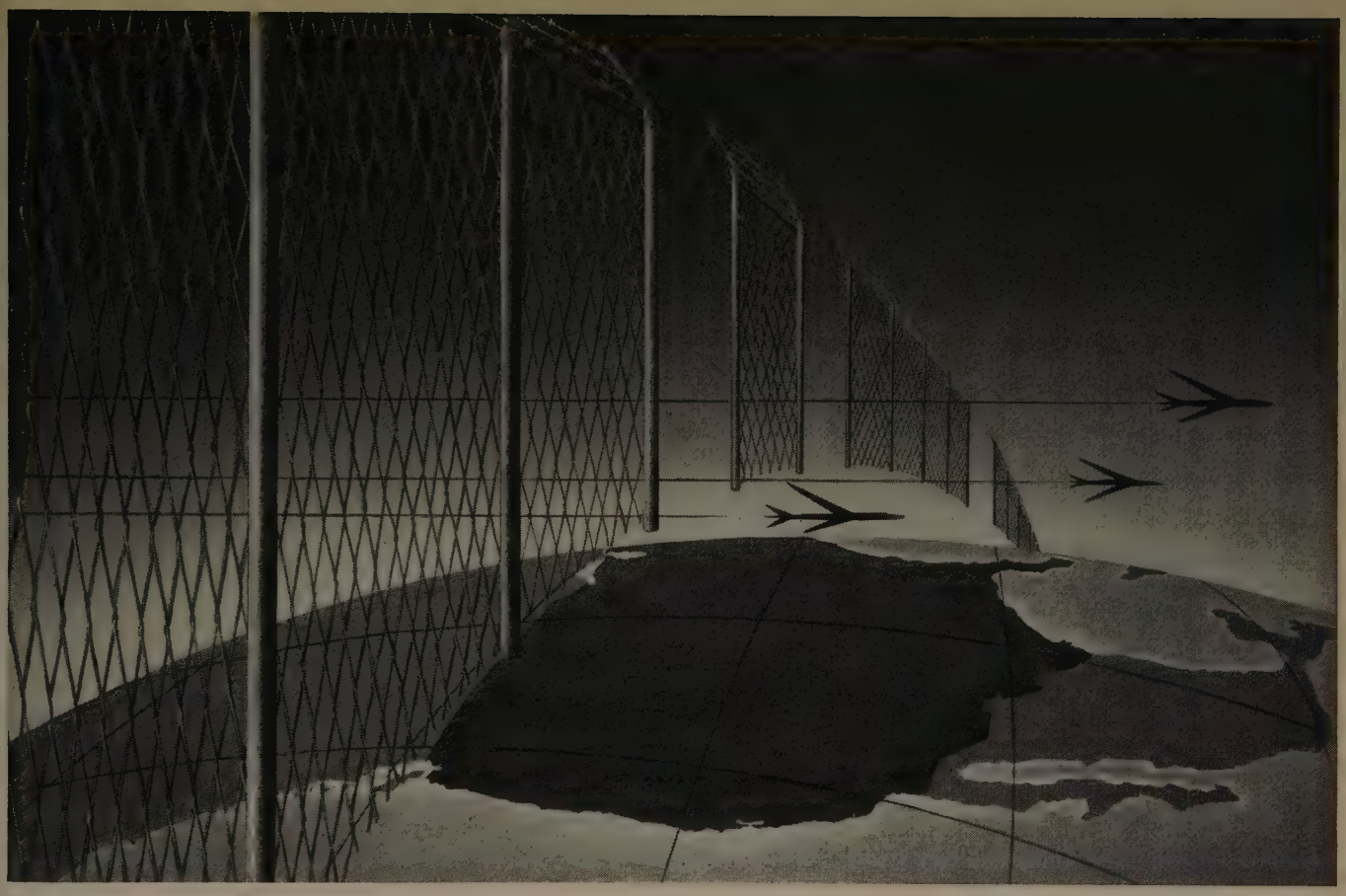
Bergen Laboratories, Booth 3947
11 Godwin Avenue
Fairlawn, N.J.

▲Max Hoberman, Fred Seekamp.

The *Volt-Ohmatic fully Automatic Vacuum Tube Voltmeter and Step-Servo for Automatic Control.

(Continued on page 144A)

* Indicates new product.
▲ Indicates IRE member.



FILLING THE GAPS IN FREEDOM'S FENCE

The possibility of low-level bombers, slipping through the continental radar fence, has been the cause of much concern in our Air Defense Command. But a new "gap filler" radar eliminates the shadow areas caused by the earth's curvature and irregularities of terrain . . . helps give instant warning of the approach of intruding aircraft.

Vital in the chain of "gap filler" radar sites is a Varian Type VA-87 klystron amplifier, sending out a million-watt pulse of power a thousand times a second on a 24-hour-a-day basis. It provides the absolute dependability necessary to our national security. Result—a radar that will operate fully automatically, for prolonged periods of time, with neither operating nor maintenance personnel at the radar site.

Complete dependability is a characteristic of *all* Varian klystrons, along with extreme ruggedness, frequency stability, and outstandingly long life in service. Write the Varian application engineering department for complete specifications on the Type VA-87, or ask your Varian representative for a copy of the Varian Catalog.

Varian is now building more than 1,000 VA-87 klystron amplifiers for the United States Air Force, for use in the AN/FPS-18 gap filler radar systems being manufactured by Bendix Aviation Corp.



VA-87C

Frequency range: 2800-2900 Mc
Peak power output: One megawatt
Duty cycle: .003
Power gain: 60db

See us at the IRE Show
Booths 2530 and 2532

THE MARK OF LEADERSHIP

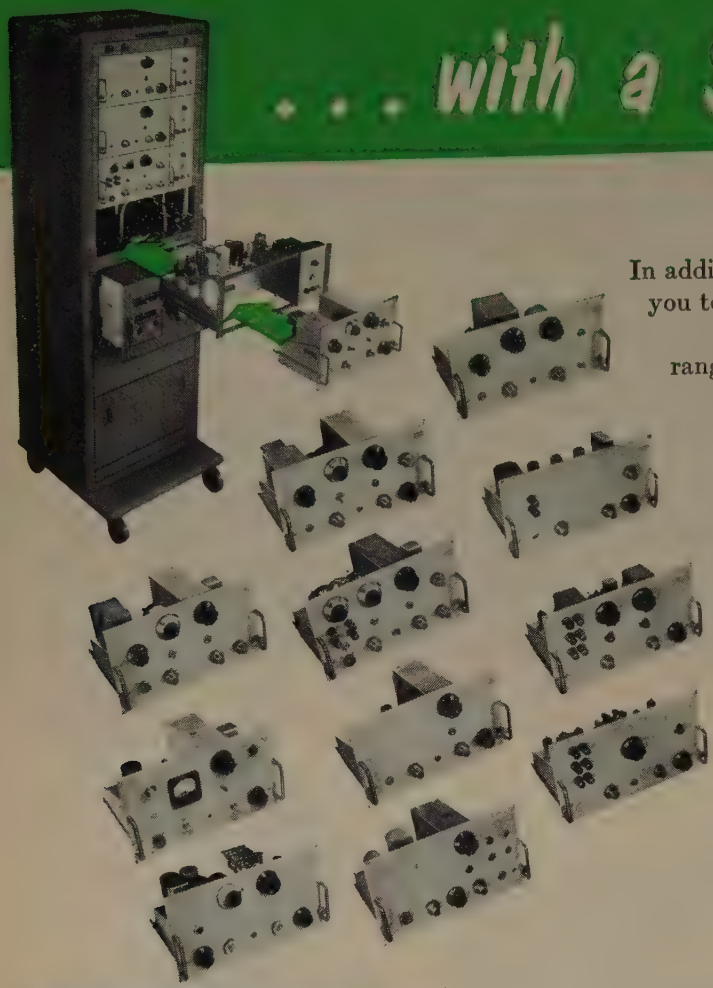
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PALO ALTO 2, CALIFORNIA

Representatives in all principal cities

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Get what you really need in oscillographic recording

. . . with a SANBORN "150"

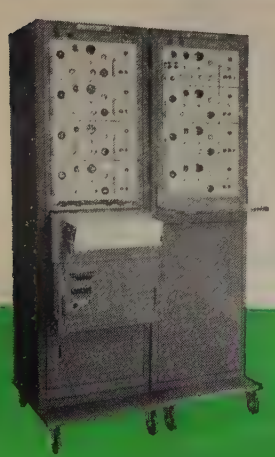


The specific advantages common
all Sanborn "150" systems are shown at the rig
In addition, the fundamental design of the Sanborn "150" allo
you to purchase and set up *only* what you need for your dire
writing oscillographic recording needs (in the 0–100 cy
range). There are no standard "150" recording systems. Ea
system in use today comprises (1) a basic assembly in t
number of channels the user needs, and (2) a *choice*
interchangeable preamplifiers according
the nature of the immediate or anticipat
measurements desired to be recorded by the us

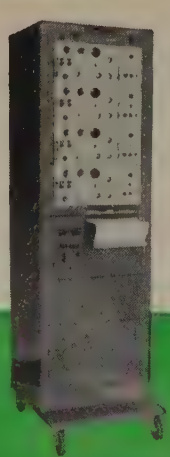
For example, the purchaser first selects either a
2, 4, 6 or 8 channel Basic Assembly, each of wh
comprises a complete Recording Assembly i
metal mobile cabinet (or portable cases if 1-channe
a Paper Take-up Unit, and for each channel a Dri
Amplifier with frame and Power Supply including Cont
Panel. Each Driver Amplifier is designed to receive,
simple plug-in connections, any of the eleven curren
available Preamplifiers listed belo

To complete his "150" Recording Syste
the user then purchases the interchangeal
Preamplifiers designed specifically for his recordi
requirements. Available "150" Preamplifiers cover a wi
range of uses and include: AC-DC Carrier, Servo Monitor, L
Level DC Coupling, Log Audio, Chopper Stabiliz
DC, AC Wattmeter, RMS Volt/Ammeter, 4
cycle Frequency Deviation, and Frequency Met
For those who wish to build special Preamplifier circuits to their o
design, a Blank Preamplifier Chas
is available which may be used along with any of the standa
Preamplifiers mentioned abo

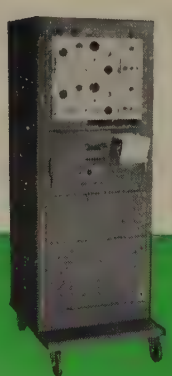
AT I. R. E. SHOW
Booths 3601 and 3603
Dynamic display of differential transformers and velocity transducers, along with complete display and demonstration of Sanborn recording systems with interchangeable preamplifiers.



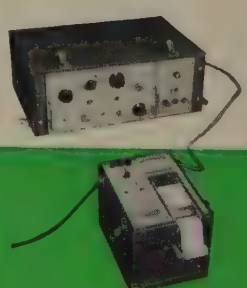
8-, 6-CHANNEL



4-CHANNEL



2-CHANNEL

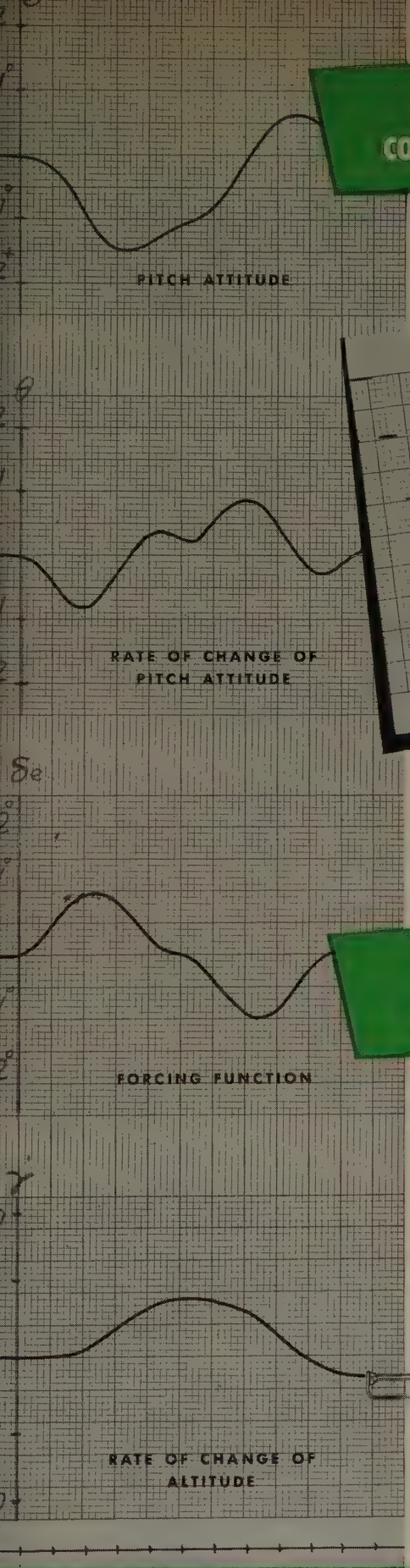


1-CHANNEL



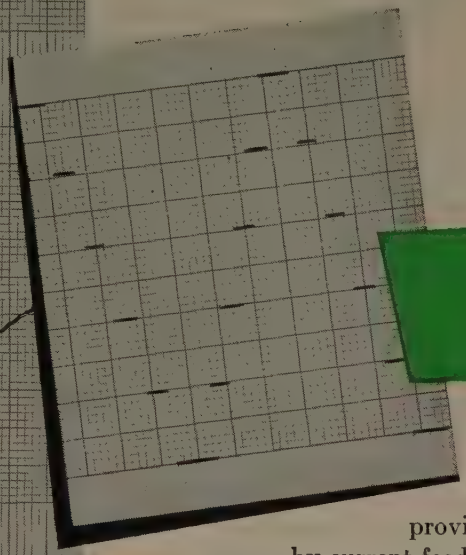


2-, 4-, 6-, 8-CHANNEL
FOR ANALOG COMPUTER READOUT SYST



TRUE RECTANGULAR COORDINATE RECORDING . . .

Sanborn "150" recordings save you valuable analysis time, and minimize the possibility of errors in interpretation, by presenting data in *true* rectangular coordinate form. Without waveform curvature, "negative" time lines, etc., traces in multi-channel records can be easily and accurately correlated, during as well as after recording.

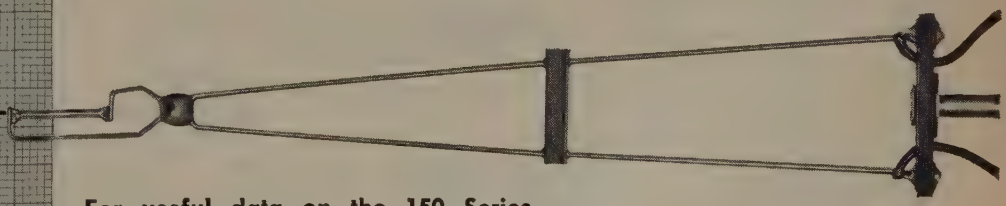


1% LINEARITY . . .

To meet your requirements for *accurate* recordings, Sanborn 150 systems provide over-all linearity of 1%. This is accomplished by current feedback driver amplifiers (one in *each* channel), and galvanometers of new design, featuring high torque (10 ma develops 200,000 dyne cm) and shorted coil frames. Maximum error over middle 4 cm of chart is 0.25 mm; over entire 5 cm chart width, 0.5 mm. Hysteresis effects have also been reduced in the recording galvanometer assembly, to further improve over-all recording accuracy.

CLEAR, SHARP, INKLESS RECORDING . . .

A third basic feature of all "150" recordings is that they are *inkless*, produced by hot ribbon stylus on heat-sensitive Sanborn Permapaper. The stylus removes the white opaque surface of the chart leaving the black undercoating to show through. Permanent and smudge-proof, the traces are characterized by sharp, blot-free peaks and notches.



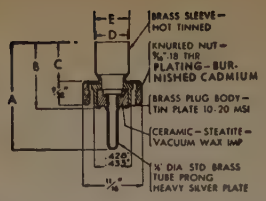
For useful data on the 150 Series systems and equipment to meet *your* needs, write to Sanborn outlining your application requirements.

SANBORN COMPANY

WALTHAM 54, MASSACHUSETTS

INDUSTRIAL DIVISION

Ideal for ANTENNA CONNECTIONS PHOTO-CELL WORK MICROPHONE CONNECTIONS



SUPPLIED IN 1 & 2 CONTACT TYPES

JONES
SHIELDED TYPE
PLUGS & SOCKETS



P-202-CCT



P-101-¼



S-101



S-202-B

LOW LOSS PLUGS AND SOCKETS FOR HIGH FREQUENCY CONNECTIONS

For quality construction thruout, and fine finish, see diagram above.
101 Series furnished with ¼", .290", 5/16", ⅜", or ½" ferrule for cable entrance. Knurled nut securely fastens unit together. Plugs have ceramic insulation; sockets bakelite. Assembly meets Navy specifications.

202 Series Phosphor bronze knife-switch type socket contacts engage both sides of flat plug contacts—double contact area. Plugs and sockets have molded bakelite insulation.

For full details and engineering data ask for Jones Catalog No. 21.

JONES MEANS *PROVEN* QUALITY

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Jones — HOWARD B. JONES DIVISION
CINCH MANUFACTURING CORPORATION
CHICAGO 24 ILLINOIS
SUBSIDIARY OF UNITED-CARR FASTENER CORP.

EPOXIDE RESIN

Cylindrical Components and BOBBINS

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Whom and What to See at the Radio Engineering Show

(Continued from page 140A)

Berkeley Division
Beckman Instruments, Inc.
2200 Wright Ave.
Richmond, Calif.
Booths 3416-3418-1728

John Scheck, ▲ Robert Melsheimer, Michael S. Dayton, Alfred Young, Wallace Rianda, C. E. Finnell, ▲ Joseph L. Hussey, William W. Harger, ▲ Thomas Thomason, ▲ R. R. Kimes, ▲ John McWaid, Fred Schott, William Estes

Digital Volt Meter, Digital Flow Meter, Nuclear Data Reduction System, EASE* Computer with DO/IT.

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New York 29, N. Y.
Booth 3107, 3109

▲ Dr. Victor Wouk, Sidney Rothman, Jesse Stitzer, G. Goldman, L. Sahud, E. Predmore, R. Lazarus, B. Aguinaldo

Air Insulated 250 KV. power supply, complete line of high voltage power supplies.

James G. Biddle Co., Booth 3008
1316 Arch Street
Philadelphia 7, Pa.

P. Emery, J. Familetti, O. X. Heinrich, A. Q. Lange, W. G. Long, A. G. Zell, S. Sommer.

Corona Testing Equipment—Frahm Relays, Oscillators, Frequency Meters—Megger Line of Electrical Testing Instruments—New Dielectric Testing Equipment.

Bird Electronic Corp.
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Cleveland 14, Ohio
Booths 3215-3217

F. B. Smith

Wattmeters, resistors, switches, filters.

Birnbach Radio Co., Inc.
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New York 13, New York
Booth 4510

Morris Birnbach, Aaron D. Danziger

Teflon hookup wire and tubing, JAN-MIL specs. Miniature and subminiature wire and cable. High temperature wire. Insulated electronic hardware. Insulated tubing and sleeving.

Bliley Electric Company, Booth 2736
Union Station Building
Erie, Pa.

G. E. Wright, ▲ J. M. Wolfskill, W. S. Riblet, ▲ R. H. Tuznik

Packaged crystal and oven for precision frequency control Type BIC-2. Quartz crystals, crystal ovens and ultrasonic delay lines.

(Continued on page 146A)

* Indicates new product.
▲ Indicates IRE member.



NOW...

two superior-quality

POWER TRANSISTORS!

A-2N301 and 2N301-A offer high power output with low distortion at high power gain

A's modern quality controls, production techniques, and test procedures continue et high standards for transistor quality. The new RCA-2N301 germanium p-n-p y type is designed specifically for audio-power output stages of auto radio, marine, tary and other mobile communications equipment. The new 2N301-A is similar to 2N301, but is designed especially for use in military and commercial equipment uiring operation at peak collector voltages as high as 60 volts.

ecially well suited to applications in mass-produced equipment, RCA-2N301 and 01-A can deliver up to 2.7 watts in class A operation; 12 watts in class B push-pull ration—with a DC supply voltage of -14.4 volts. Total harmonic distortion at ximum-signal power output is less than 10%.

good electrical contact and excellent thermal conductivity to the heat sink, A-2N301 and 2N301-A utilize a special mount structure in which the collector is trically and thermally connected to a mounting flange.

ong the outstanding design features are: high gain • high alpha cutoff frequency w thermal resistance • low leakage and low saturation currents • excellent current linearity over the full range of the collector current • high operating stability cellent electrical uniformity.

TECHNICAL DATA—MAX. RATINGS (ABSOLUTE VALUES)	2N301	2N301-A
Collector-to-Base Voltage		
DC (for inductive load)	-20 max.	-30 max. volts
Peak	-40 max.	-60 max. volts
Dissipation (mounting flange temp. 55°C)	12 max.	12 max. watts

TYPICAL OPERATION FOR 2N301 & 2N301-A (AMBIENT TEMP. 55°C)	CLASS A	CLASS B
DC Supply Voltage	-14.4	-14.4 volts
Max.-Sig. Power Output	2.7	12 watts
Power Gain	32.5 db	30 db
Circuit Efficiency	47%	67%
Total Harmonic Dist.	10%	10% max.

CHARACTERISTICS AT MOUNT. FLANGE TEMP. 25°C	
DC Collector-to-Emitter Voltage	-1.5 volts
DC Collector Current	-1.0 amp.
Large-Signal DC Current Transfer Ratio	70

Your RCA Field Representative will be glad to discuss the many advantages offered by RCA Power *Transistors* for your specific designs. Contact him at the RCA office nearest you.

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MIDWEST. . . Suite 1181, Merchandise Mart Plaza, Chicago, Illinois WHitehall 4-2900

WEST . . . . . 6355 E. Washington Blvd. Los Angeles, Calif. RAymond 3-8361

GOVERNMENT 224 N. Wilkinson Street Dayton, Ohio HEmlock 5585
1625 "K" Street, N.W. Washington, D.C. District 7-1260

For technical data on RCA-2N301 and 2N301-A, write RCA Commercial Engineering, Sec. C35NN, Somerville, N.J.

RCA®

TRANSISTORS

RADIO CORPORATION OF AMERICA

Semiconductor Division • Somerville, N. J.

RADIO INTERFERENCE AND FIELD INTENSITY *measuring equipment*

Stoddart equipments are suitable for making interference measurements to one or more of the following specifications:

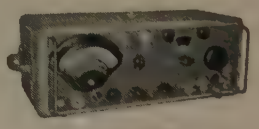
AIR FORCE—MIL-I-6181B
150 kc to 1000 mc
BuAer—MIL-I-6181B
150 kc to 1000 mc
BuShips—MIL-I-16910A (Ships)
14 kc to 1000 mc
SIGNAL CORPS—MIL-I-11683A
150 kc to 1000 mc
SIGNAL CORPS—MIL-S-10379A
150 kc to 1000 mc

The equipments shown cover the frequency range of 14 kilocycles to 1000 megacycles.

Measurements may be made with **PEAK, QUASI-PEAK and AVERAGE** (Field Intensity) detector functions. **QUASI-PEAK** values meet **ASA** recommendations and can be provided to meet **CISPR** (International) recommendations.

F.C.C. PART 15—Now in effect, the revised F.C.C. Part 15 places stringent requirements upon radiation from incidental and restricted radiation devices. Stoddart equipment is suitable for measuring the radiation from any device capable of generating interference or c-w signal within the frequency range of 14 kc to 1000 mc.

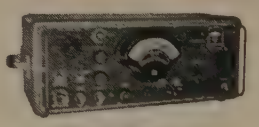
Write Stoddart Aircraft Radio Co., Inc., for your free copy of the new revised F.C.C. Part 15.



NM-10A (AN/URM-6B)
14 kcs to 250 kcs



NM-20B (AN/PRM-1A)
150 kcs to 25 mcs



NM-30A (AN/URM-47)
20 mcs to 400 mcs



NM-50A (AN/URM-17)
375 mcs to 1000 mcs



The **Stoddart NM-40A** is an entirely new radio interference-field intensity measuring equipment. It is the commercial equivalent of the Navy type AN/URM-41 and is tunable over the audio and radio frequency range of **30 CPS to 15 kc.** It performs vital functions never before available in a tunable equipment covering this frequency range. Electric and magnetic fields may be measured independently over this range using newly developed pick-up devices. Measurements can be made with a 3 db bandwidth variable from 10 CPS to 60 CPS and with a 15 kc wide broadband characteristic.

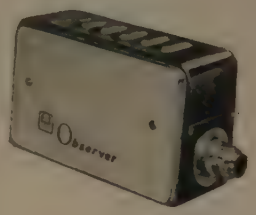
STODDART *Aircraft Radio Co., Inc.*
6644-E SANTA MONICA BLVD., HOLLYWOOD 38, CALIFORNIA • Hollywood 4-9294

Whom and What to See at the Radio Engineering Show

(Continued from page 144A)

Blonder-Tongue Laboratories, Inc.
526 North Ave., Westfield, N. J.
Booth 1210

Joseph H. Kerner, Joseph H. Gibbs, Robert McKiernan, Thomas Shea, Richard Lontka



B-T LABS

OBSERVER TV CAMERA

Industrial TV monitors, TV camera, field strength meter, solderless co-ax connectors, cable stripper, attenuator, VHF amplifiers, UHF convertors, cable couplers, radiation-proof housings, audio-video modulator.

Bodnar Industries, Inc., Booth 4051
238 Huguenot St.
New Rochelle, N. Y.

A. S. Bodnar, B. J. Bodnar, ▲ Stanley Fisher, John F. Bodnar

Integral Lighting of Meters and Instruments (Air Force Exhibit), WCLSI-2-204; MIL-P-7788 (AN-P-89) Plastic Lighting Plates, Dials, etc.; Railway Electronics Telegraph Bias and Distortion Meter.

Boeing Airplane Co.
P. O. Box 3707
Seattle 24, Wash.
Booth 1116

John C. Sanders

High speed airplanes & guided missiles, electronics applicable to production.

Boesch Mfg. Co., Inc. Booths 4301-4302
45 River St.
Danbury, Conn.

A. H. Boesch, Francis D. Schatzle, Henry S. Walendzik, William W. Clarke, Arthur Melillo, Gordon Hatch.

Model P-TW Toroidal Coil Winding Machine arranged to accomplish progressive wound toroidal coils. This is an entirely new development in the toroidal winding field. Also Boesch Series TW 200, TW 201, and SM Toroidal Winder with electronic Turns Counter.

Bogart Manufacturing Corp., Booth 3226
315 Seigel Street
Brooklyn 6, N. Y.

▲ H. Kagan, ▲ V. J. Albanese, S. Lapidus, N. Mintz, L. N. Blatt, G. A. Zanis

Coaxial balanced riding hybrid.

(Continued on page 149A)

* Indicates new product.
▲ Indicates IRE member.

Every exhibitor has something to interest you. Be sure to visit all four floors for 800 new ideas.

Whom and What to See at the Radio Engineering Show

(Continued from page 146A)

Bogue Electric Mfg. Co.
52 Iowa Ave., Paterson 3, N. J.
Booths 2115-2117
P. Wexler, R. Sachs, D. Russin, I. Weinstein, J. Rambusek, H. Skarrett



*High power 10 watt silicon transistor on display with various application test devices.

Bomac Laboratories, Inc.
Salem Road, Beverly, Mass.
Booths 3815-3817
▲ Richard J. Broderick, ▲ Earle D. Benson, ▲ Harold Heins, ▲ George E. Carter, Jr., James F. Dean, Philip A. Bagnell, Robert W. Andrews

Magnetron 5780. Complete line of gas switching tubes, klystrons, reference cavities, shutter tubes, pressurizing windows, and silicon diodes.

Bond Electronics Corp., Booth 2405
60 Springfield Ave.
Springfield, N. J.
E. R. "Pete" Vizard, Fred Hall, Edmund Kaiser, Vincent J. Bonadies

Encapsulated wire-wound resistors; hermetic sealed wire-wound resistors; sub-miniature wire-wound resistors; high power wire-wound resistors; low power precision MIL-R-93 W.W. resistors.

Boonton Electronics Corp.
738 Speedwell Ave.
Morris Plains, N.J.
Booth 3121
▲ Ernest A. Porter, ▲ J. H. Mennie, John M. Young, ▲ Earle Dilatush

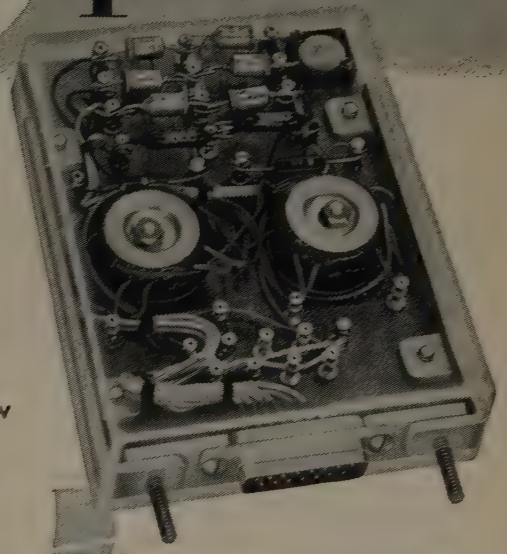
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*Sensitive RF Voltmeter to 500 MC
*RF Distortion Meters 0.1 to 100 MC
Three Terminal Capacitance Bridge
Capacitance Temp. Coef. Equipment
UHF Grid Dip Meter 300-1000 MC
BOOTH 3121
Boonton ELECTRONICS Corp.
Morris Plains, New Jersey

Boonton Molding Co., Booth 4046
326 Myrtle Ave.
Boonton, N. J.
Fred Stanley
Pottings, moldings.

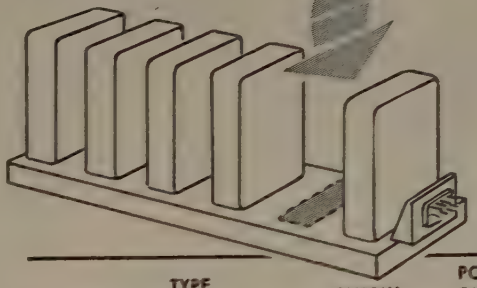
(Continued on page 150A)

* Indicates new product.
▲ Indicates IRE member.

Lightweight! SERVO
Magnetic Amplifiers



The servo amplifiers illustrated are typical standard types. Other models, including higher power types, are available for systems engineering. The complete MA line offers the designer a choice of compact, low cost types, amplifiers featuring fast response at high gain and all-magnetic models providing highest performance.



In addition to standard types, custom designs can be produced for special applications, or complete servo and automatic control systems can be engineered to your requirements.

TYPE	SUPPLY	POWER OUTPUT	SENSITIVITY	RESPONSE TIME—SEC.
LIGHTWEIGHT SUB-MINIATURE MAGNETIC AMPLIFIER	115 volts 400 cps.	½, 3, 5, 10 watts	.02 volts	.003
MAGNETIC PRE-AMP + SATURABLE TRANSFORMERS	115 volts 400 cps.	3, 5, 6, 10, 18 watts	1 volt AC	.03
MAGNETIC PRE-AMP + HIGH GAIN MAGNETIC AMPLIFIER	115 volts 400 cps.	5, 10, 15, 20 watts	0.1 volt AC	.008 to .1
TRANSI-MAG*: TRANSISTOR + HIGH GAIN MAGNETIC AMPLIFIER	115 volts 400 or 60 cps.	2, 5, 10, 15, 20 watts	.08 volt AC into 10,000 ohms	.01

Call or write for new illustrated bulletins.

Magnetic Amplifiers • Inc
632 TINTON AVE., NEW YORK 55, N. Y.—CYpress 2-6610
West Coast Division
136 WASHINGTON ST., EL SEGUNDO, CALIF. — EAstgate 2-2056

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OUTSTANDING FEATURES

Resilient Insert • Solid Shell Construction • Low Engagement Forces • Closed Entry Sockets • Positive Contact Alignment • Contacts—heavily gold plated • Cadmium Plate—clear irridite finish • Temperature range −67° to +250°F. • Easily Pressurized to Latest MIL Specifications.

Here is the new and improved Bendix Type SR rack and panel electrical connector with outstanding resistance to vibration. The low engagement force of this connector gives it a decided advantage over existing connectors of this type.

Pressurization is easily accomplished. The resilient inserts press firmly against the shell wall holding the contacts in exact position. Insert patterns are available to mate with existing equipment in the field.

Adding to the efficiency of this rack and panel connector is the performance-proven Bendix "clip-type" closed entry socket.

Here, indeed, is another outstanding Bendix product that should be your first choice in rack and panel connectors.

Bendix SCINTILLA DIVISION of Bendix
SIDNEY, NEW YORK

Export Sales and Service:
Bendix International Division, 205 East 42nd St., New York 17, N. Y.

FACTORY BRANCH OFFICES:
117 E. Providencia Ave., Burbank, Calif. • Paterson Building, 18038 Mack Ave., Detroit 24, Mich. • 545 Cedar Lane, Teaneck, N. J. • 5906 North Port Washington Rd., Milwaukee 17, Wisc. • Hulman Building, 120 W. Second St., Dayton 2, Ohio • 2608 Inwood Road, Dallas 19, Texas • Boeing Field, Seattle 8, Washington • 1701 "K" Street, N.W., Washington 6, D. C.

Whom and What to See at the Radio Engineering Show

(Continued from page 149A)

Boonton Radio Corp.
Intervale Rd., Boonton, N. J.
Booths 3101-3102

▲ G. A. Downsbrough, ▲ W. C. Moore, ▲ F. C. Marble, ▲ N. U. Riemanschneider, D. K. Stevens

Q Comparator (New production Q and L indicator), Q Meters, RF Bridges, RF Voltage Standard, FM-AM, aircraft navigation and sweep Signal Generators, Film Thickness Measurements.

Borden Company, Booth 4011
P.O. Box 1589
Santa Barbara, Calif.
SEE: RESIN INDUSTRIES, INC.

Borg Equipment Div., George W. Borg Corp.
120 S. Main St., Janesville, Wis.
Booths 3840 & 3842

R. K. Johnson, John Arnold, B. Mackey, J. Chevalier



Borg announces miniature trimming potentiometer which provides the smallest size, greatest resolution, and highest power capabilities in a rectangular cased unit for screwdriver adjustment.

Borg-Warner Corp, Booth 3506
3300 Newport Ave.
Santa Ana, Calif.
(See: B. J. Electronics Div.)

Bourns Laboratories
6135 Magnolia Ave., Riverside, Calif.
Booths 3716, 3718

Carl E. Calohan



Potentiometers, accelerometers, trimpot.

Bowmar Instrument Corp., Booth 1903
2415 Pennsylvania St.
Fort Wayne 4, Indiana

Edward A. White, William S. Caley, Lowell D. Temple

Compact internal pinion type counters capable of operating at speeds above 500 rpm.

(Continued on page 152A)

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RF FIELD ENGINEERING SERVICE

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SPECIALTY CAPACITORS

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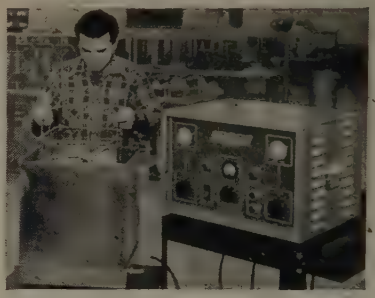
Whom and What to See at the Radio Engineering Show

(Continued from page 150A)

Bradley Laboratories, Inc., Booth 2919
168 Columbus Ave.
New Haven 11, Conn.
William J. Gagnon
Selenium and copper oxide rectifiers and self-generating photoelectric cells.

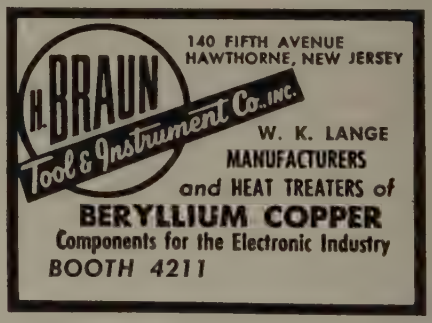
W. H. Brady Co., Booth 4205
727 W. Glendale Avenue
Milwaukee 12, Wisconsin
T. W. Wise, J. I. Stone, F. C. Klushman, J. J. Duffy, P. Vienot
Black 'N White Printed Circuit Drafting Aids, Miniature Markers for identifying sub-miniature components, Positive Placement Insulation for close tolerance insulation, Polyester and Vinyl Wire Markers for wire identification.

Branson Ultrasonic Corp.
37 Brown House Rd.,
Stamford, Conn.
Booth 3045
Peter K. Bloch, Norman C. Branson, Michael Tamas, Kenneth Hayes, Walter Bleistein, Everett Harris, Frank Hightower, Donn Costanzo



Will exhibit latest style ultrasonic generators. Featuring new ten foot long stainless steel cleaning tank designed for conveyorized cleaning of printed circuit boards and other electrical components.

H. Braun Tool & Instrument Co., Inc.
140 Fifth Ave., Hawthorne, N. J.
Booth 4211
W. K. Lange, J. Kahlke, R. Boderek, E. Olmstead, E. Clarke

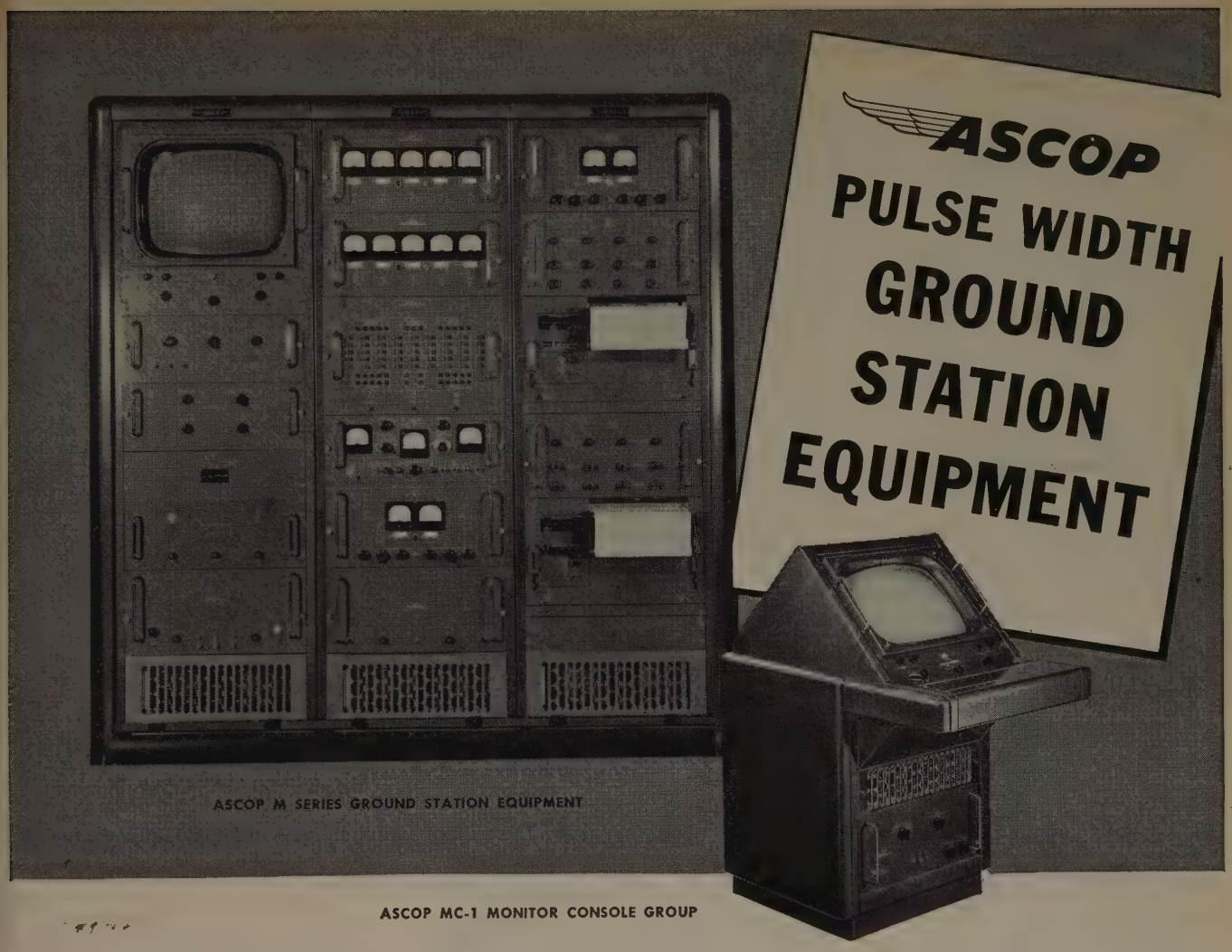


Electronic—Grid Contacts, Cavity Contacts, Crystal Contacts, Silbond Contacts, Contact Cathodes, Spring Selectors, Diaphragms, Grounding Strips, Fuse Clips, Screen Plates and Gaskets.

(Continued on page 156A)

* Indicates new product.
▲ Indicates IRE member.

First Aid Room
Mezzanine of First Floor, Northwest Corner—Take Elevator 20



ASCOP M SERIES GROUND STATION EQUIPMENT

ASCOP MC-1 MONITOR CONSOLE GROUP

Achieves System Accuracies of Better Than 1%









ASCOP Pulse Width Ground Station equipment, pictured above, complements ASCOP's PW Multicoders and Radio Telemetering Sets to provide complete "packaged" systems for operational testing of aircraft, missiles and other vehicles . . . and for static testing of engines, rockets, nuclear reactors and other powerplants.

Continuous automatic compensation of system zero and scale factor eliminates the need for critical components and frequent manual adjustment.

The M Series Ground Station uses intermediate magnetic tape speed change to operate directly from pulse width signals of 30x30, 45x20, or 90x10 configurations—or from any non-standard configuration having 30, 45 or 90 channels. All data channels may be visually monitored simultaneously.

All ASCOP equipment is designed for dependable accuracy, simplicity of operation, maximum life with minimum maintenance attention. ASCOP engineers will gladly consult with you, without obligation, on your current projects. Or write for detailed information, outlining your system requirements.



Stations are sold only as combinations of standard or special tape recorder, monitor, decommutation or output recorder groups.

PROVIDES FOR:

- **Advance Station-Calibration, using locally generated setup signals**
- **Continuous Automatic Compensation for system zero, scale factor changes**
- **Simultaneous Visual Monitoring of all data channels**
- **Missing Data Point Correction, for continuous synchronization**
- **Real Time Reduced Output Records for any or all channels**
- **Easy Access to Slide Mounted Chassis, even during operation**

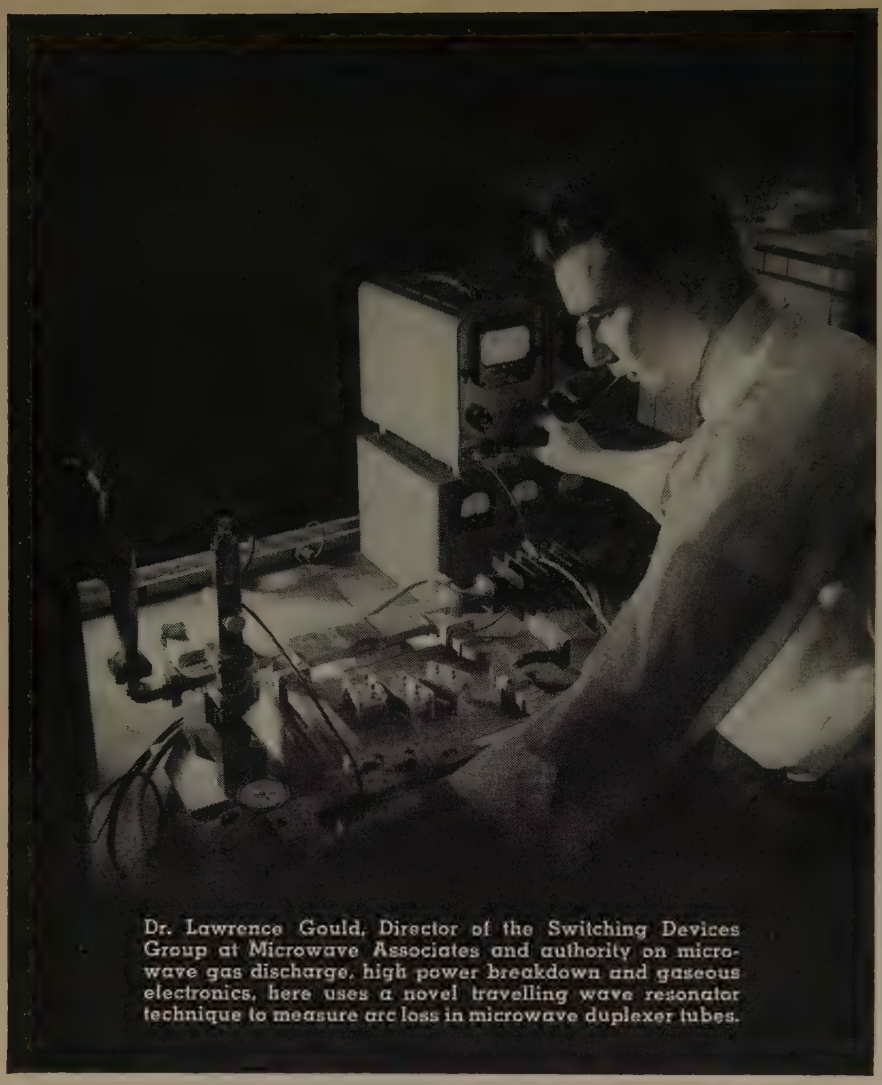
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Crestview 1-8870



Dr. Lawrence Gould, Director of the Switching Devices Group at Microwave Associates and authority on microwave gas discharge, high power breakdown and gaseous electronics, here uses a novel travelling wave resonator technique to measure arc loss in microwave duplexer tubes.

...fast switch for tomorrow's power

New duplexer gas discharge program at Microwave Associates focuses basic research and development effort on switching tubes . . . today's weakest link in tomorrow's high power systems.

The rapidly expanding Microwave Associates Switching Devices group, under the supervision of Dr. Lawrence Gould, is engaged in a comprehensive program to determine the high power characteristics of gas discharges and their interaction with related microwave circuits.

This project, aimed at developing more effective TR switching tubes and duplexers having minimum arc loss, minimum recovery time and maximum bandwidth, is part of Microwave Associates' continuing program of product improvement.

Special measurement techniques have been developed by Dr. Gould and his associates to insure better control of tube operating characteristics, longer life and increased reliability in microwave duplexer systems.

This program is expected to determine the practical ultimate limitations of a gas discharge for high power switching. Progress of the program has already been directly reflected in higher power ratings and improved design for Microwave TR tubes.

CAN YOU USE THIS HELP?

Are you facing problems in higher powers and better TR tube performance? A phone call to Dr. Gould will bring you immediate benefits from the results of this continuing program. Microwave Associates urgently invites you to work in close liaison with our research group.

MICROWAVE ASSOCIATES INC.

BURLINGTON, MASSACHUSETTS • BU 7-2711

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Whom and What to See at the Radio Engineering Show

(Continued from page 152A)

Brevel Products Corp.
601 West 26th Street
New York 1, N. Y.
Booth 4415

Robert O. Soman, George Hirsch, Arnold Pales, R. H. Winslow, Russ Sebright, Jerry Golten

Slow-speed Fractional H.P. worm & spur geared motors.

The Bristol Co., Booth 3932
Waterbury 20, Conn.

G. P. Lonergan

Recording & controlling electronics instruments, choppers, relays, switches, transducers.

British Consulate, Booth 2005
99 Park Avenue
New York, N. Y.

Francis Pelly

General information on British electronic corporations.

British Industries Corp.
80 Shore Rd.
Port Washington, L.I., N. Y.
Booths 2004-2922

Leonard Carduner, ▲ William Carduner, Franklin S. Hoffman, Jay H. Quinn, Arthur Gasman, Irwin Lubalin

KT88 and KT66 Genalex Audio Tubes. Garrard transcription equipment and record changers. Multicore Solder with Ersin Flux. Widney-Dorlec cabinet component systems.

British Industries Corp., Instrument Div.
80 Shore Rd.
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Booths 2004-2922

Leonard Carduner, Eugene Carduner, S. Bosworth, ▲ Wm. S. Douglas, L. Holtz, Irving Hoffman



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Servomex Low-Frequency Generator with 37 output waveshapes. H. W. Sullivan most accurate standards of RLC, and precision laboratory instruments. A Reid Automatic Dip Solder Bath for printed circuits, and S. G. Brown headphones.

British Radio Electronics, Ltd., Booth 2001
1833 Jefferson Place, N.W.
Washington 6, D.C.

▲ F. D. Harris, P. O. Harris, C. R. Beaton, A. Axelrod, R. A. Bodholt

OXLEY "TEMPERATURE"—TEMPERATURE COMPENSATING AIR DIELECTRIC TRIMMER. EGEN Sub-miniature Potentiometers. OXLEY Feed-through Insulators and Air Trimmers. SRC Precision Silvered Mica and Ceramic Capacitors. "Electronic and Radio Engineer" and "Wireless World" Magazines.

(Continued on page 158A)

CLEVITE

JAN Types
High Temperature Types
High Conductance Types
High Resistance Types

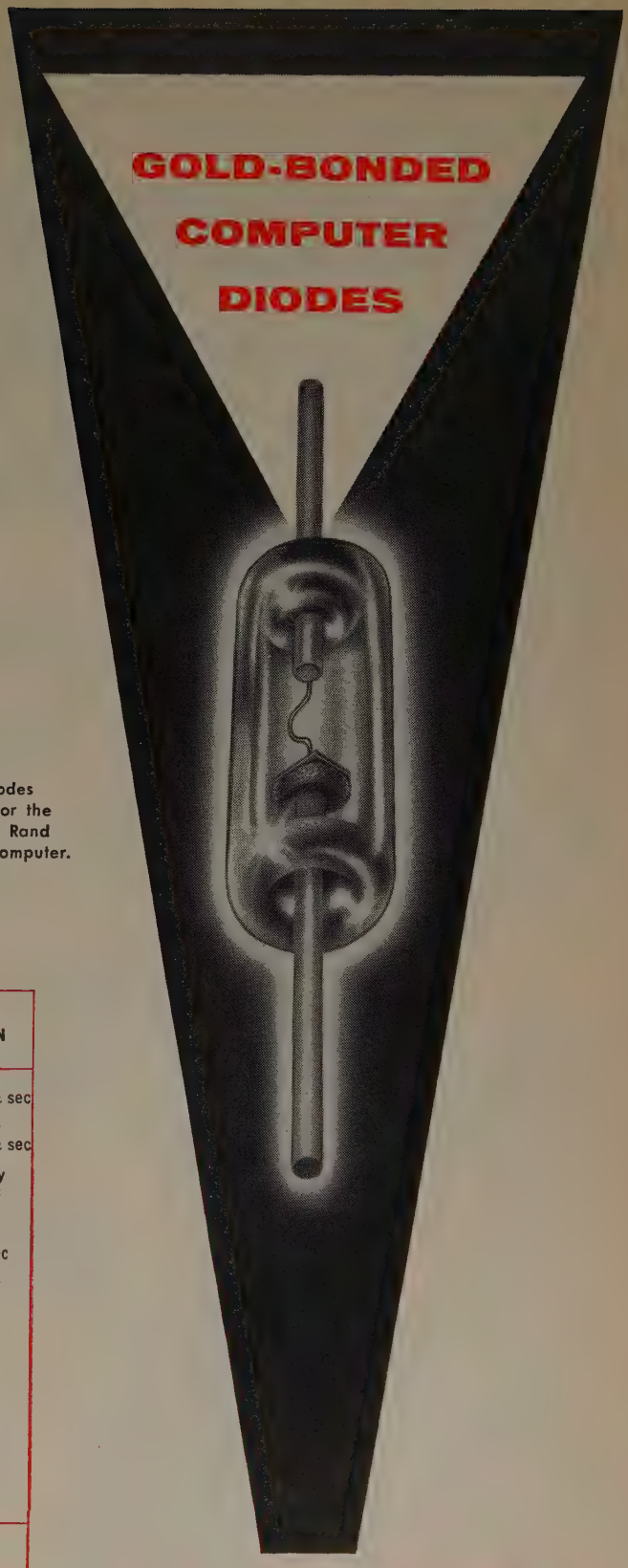
All CLEVITE gold-bonded subminiature glass diodes feature high forward conductance . . . high inverse resistance . . . fast pulse recovery . . . and fast forward switching time.

CLEVITE gold-bonded diodes are now used by the nation's leading computer manufacturers. If you have similar requirements, our engineers will be glad to discuss them. Contact us for complete information and data sheets.

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Clevite diodes are used for the Remington Rand UNIVAC computer.



CHARACTERISTICS

TYPE	Forward Current at +1V (ma. Min.)	Inverse Current at Specified V (μa. Max.)	Continuous Inverse Operating Voltage	DESCRIPTION
CTP-301	40	25 @–50V	50	Inverse recovery time meas. 1.0 μ sec
CTP-307	300	20 @–30V	40	Inverse recovery time meas. 1.0 μ sec
CTP-309	300	20 @–6V	20	Forward recovery time 0.1 μ sec
CTP-318	50	500K between –10V &–50V	60	Inverse recovery time 0.3 μ sec. Forward 0.1 μ sec
CTP-319	150	500K between –20V &–90V	90	Inverse recovery time 0.3 μ sec
CTP-320	5	50 @–50V	80	Inverse recovery time 0.3 μ sec
CTP-328	7.5	500K between –10V &–60V	60	Inverse recovery time 0.3 μ sec
IN34A	8.5	30 @–10V 500 @–50V	60	General Purpose
IN279	100	200 @–20V	30	General Purpose
IN116	5	100 @–50V	60	General Purpose

Available JAN Types — 1N127, 1N128, 1N198, 1N277, 1N281

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TRANSISTOR PRODUCTS

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Other Clevite Divisions



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at point of strain

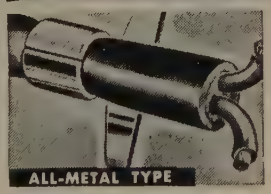
Protect product saleability too — by insuring long life for cords, cables and conductors. Genuine "GRIPMASTER" Strain Reliefs provide these vital features—

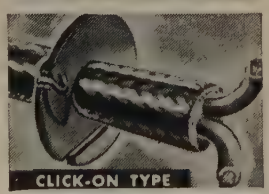
- ★ Anchor cords to housing
- ★ Eliminate taping or threading
- ★ Prevent unraveling
- ★ Prevent cord pull damage
- ★ All sizes and styles
- ★ Easy to apply
- ★ Inexpensive

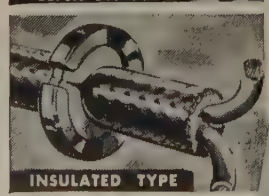
Gripmaster Strain Reliefs are "tremendous trifles" that make good products better!

Ask for samples.

4 WAYS TO END ALL CORD AND CABLE SERVICE FAILURES *Economically*



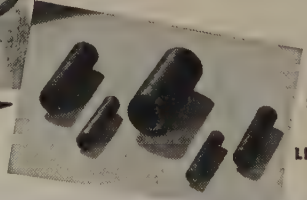




GRIPMASTER STRAIN RELIEFS

Interruptions due to cable and cord connection failures are eliminated because they anchor the cord to the product at the point of strain. GRIPMASTER Strain Reliefs can withstand pulls up to 100 lbs., and are acceptable to Underwriters Laboratories. All types Reg. U. S. Pat. Off.

WIRE BINDING SLEEVES—Preventing fraying of cord ends, these specially-treated rubber tubes are available in five sizes to fit wires to .790



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STRAIN RELIEF SPECIALISTS

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Whom and What to See at the Radio Engineering Show

(Continued from page 156A)

Brubaker Electronics, Booth 2128
Jack Baker
Oscillogram reader, four digit teleducer, complete line of gyros (exploded and mounted, uncovered, and cased), marker pulser and a variety of precision components to include delay lines, relays, pulse transformers and switches.
See Whittaker Gyro & Telecomputing Corp.

Brush Electronics Company, Booths 2616-2626
3405 Perkins Avenue
Cleveland 14, Ohio
Edward F. Crafts
Magnetic recording components, piezo electric crystals & ceramics, acoustics.

Buchanan Electrical Products Corp., Booth 4213
225 U. S. Route 22
Hillside, N. J.
Paul E. Vance, J. O. Johnson, D. E. Andersen, William Cusick, George Ustin, Kenneth Todd
* Sectional medium-duty terminal block and * production-line solderless terminal lugs will be demonstrated.

Buckbee Mears Company
Lindeke Building, 4th & Rosabel Sts., St. Paul 1, Minnesota
Booth 3809
Norman B. Mears, Norman C. Mears, Arnold T. Wicklund, Marvin C. Cook
Etched and electroformed parts. Including tube mesh, special etched grids, fine line glass rulings for producing mesh and optical specialties.

Budd-Stanley Co., Inc.
43-01 22nd St., Long Island, City 1, N.Y.
Booth 3114
Stanley Gartman, Bud Meyers, Jules Simmonds, Sig Goldstein
Microwave transmission equipment including complete front end assemblies, waveguide duplexers, mixers, antenna feed systems, rotary joints in all materials and featuring our unique casting process.

Budd-Stanley Co., Inc. Mechanical Div.
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Long Island City 1, N.Y.
Booth 4130
J. Liebman, Budd Meyers, E. Gotthold
Precision investment casting and plaster mold castings.

Bulova Watch Co., Inc., Dept. of Government & Industrial Sales, Booth 3930
Bulova Park
Flushing 70, N.Y.
R. A. Lockwood
Cameras, aperture controls, automation systems, Piezo electric crystals units, aircraft instruments.

(Continued on page 160A)

* Indicates new product.
▲ Indicates IRE member.

PROVE IT YOURSELF!

ULTRA-HIGH POLYSTYRENE PRECISION CAPACITORS

as low as 0.1% tolerances in most values!

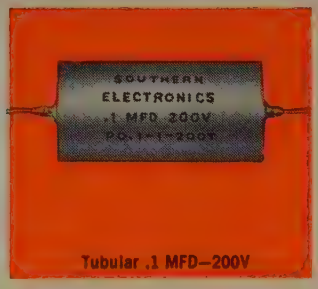
Leading engineers know that S. E. C. pioneered the current polystyrene capacitors in Guided Missiles and Analog Computers. S. E. C. test data and engineering experience is based on years of research and constant improvement of product.

S. E. C. products have proved the answer to many tough engineering problems by such leading *analog computer manufacturers as;* Electronic Associates, Reeves Instrument, Beckman Instrument, Mid-Century Instrumatic, Goodyear Aircraft, Donner Scientific, Boeing Airplane Company and such *military contractors* as Northrop Aircraft, Gilfillan Brothers, North American Aviation, Convair, Motorola, Farnsworth Electronics, Bendix Aviation, Federal Tele-Communications and many others.

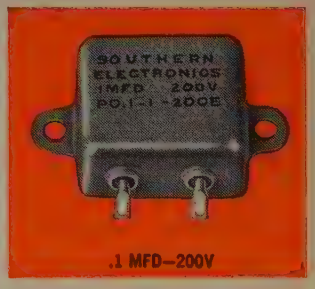
R. & D. establishments as M.I.T., Jet Propulsion Labs, Cornell Aeronautical Labs, Battele Memorial Inst., Sandia Corp., and many others have chosen S. E. C. engineered components for their prototypes.

Check these outstanding features for yourself:

- Tolerances as close as 0.1%
- Insulation Resistance as HIGH as 1×10^{12}
- Dielectric Absorption as LOW as .0001
- Dissipation Factor as LOW as .0002
- Temperature Coefficient...100 PPM per °C.
- Stability as close as .05% drift in 1 yr.
- Voltage derating . . . none to 170°F.
- *Hermetically sealed for enduring accuracy!*

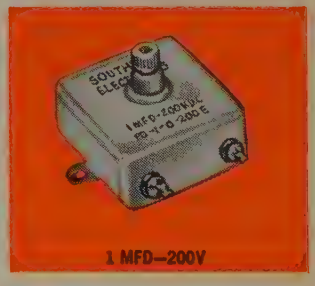


Tubular .1 MFD—200V



.1 MFD—200V


10 MFD ±1% 200V
4-7/16 x 3-1/16 x 2-1/8


1 MFD—200V

For your most exacting requirements—always specify S. E. C.

SOUTHERN ELECTRONICS *Corporation*

239 West Orange Grove Avenue
Burbank, California
PIONEERS IN CUSTOM PRECISION CAPACITOR ENGINEERING

See us in Booth 2309—IRE Show—N. Y.

RCA INSTRUMENTS OF LABORATORY PRECISION



RCA VACUUM TUBE VOLTMETER
Type LV-10, Price $250*
Also ask about Null Voltmeters.

THIS VACUUM TUBE VOLTMETER is extremely versatile, combining in one instrument an AC Voltmeter—covering a range from audio to UHF frequencies, a DC Voltmeter—with 100 megohms input resistance, and an ohmmeter capable of measuring resistance from zero to 1000 megohms. Ideal for use wherever highly precise measurements are essential. Maximum stability and low current consumption are outstanding features. Balanced indicating movement makes this exceptional instrument suitable for use lying flat, standing vertically or inclined.

For complete information on the above and other instruments in the RCA line, write to RCA, Dept. P-94, Building 15-1, Camden, N.J.

*Price in U.S.A., f.o.b. Camden, N.J. Subject to change without notice.

DC VOLTS
7 ranges: 1, 3, 10, 30, 100, 300, 1,000.
Accuracy: ±3% full scale deflection.
Input resistance: 100 megohms ±2% on all ranges.

AC VOLTS
6 ranges: 1, 3, 10, 30, 100, 300.
Sine Wave Accuracy: ±3% full scale deflection.
Input impedance: Less than 2 mmf in parallel with 15 megohms.
Frequency Response: ±1.0 db, 18 cps to 700 MC.
Relative Measurements: possible to 1,000 MC.

RESISTANCE: 0 to 1,000 megohms in 7 ranges.
Accuracy: ±5% between divisions 10 and 100 on scale.
DB Range: —10 to +52 dbm in 6 ranges.
Zero dbm=1 mw in 600 ohms.

RADIO CORPORATION OF AMERICA
COMMERCIAL ELECTRONIC PRODUCTS
CAMDEN, N.J.
In Canada: RCA VICTOR Company Ltd., Montreal

Instrument Engineering Representatives in Principal Cities

Whom and What to See at the Radio Engineering Show

(Continued from page 158A)

Burgess Battery Co., Booth 2711
Foot of Exchange St.
Freeport, Ill.

W. F. Gallagher, R. C. Clock, Leo Heinen

Complete line of Dry Batteries including new Activator Batteries for Transistor Circuits; Complete line of Reserve Power Units; and portable lamps and flashers called Radar-Lamp, Radar-Lite and Radar Flash.

Burlingame Associates, Ltd., Booths 3610-3612
103 Lafayette Street
New York 13, N. Y.

H. Bogin, ▲ Roland Reisley, ▲ G. Sullivan, ▲ A. Ackerman, ▲ B. Aulde, ▲ A. Beckman, ▲ R. Bullock, ▲ G. Case, ▲ R. Crane, ▲ G. Gostenhofer, ▲ G. James, ▲ D. Kadushin, ▲ M. Maloy, ▲ C. Smoll, ▲ J. Takakjian, ▲ J. Randall

Coordinated Test Equipment display and Advanced Precision Miniature Oscilloscopes; Allison Adjustable Band-Pass Filters 15 cps—640 kc

Burndy Corp., Booth 4424
Omaton Division
Norwalk, Conn.

Alan E. Aune, Lewis E. Gage, Ray Smith, James Lambert, Sid Schulman.

One-piece insulated UNIRING, shielded and coaxial cable connector; Full line of electrical and electronic connectors and components, and installation tooling.

Burnell & Co., Inc.
45 Warburton Ave.,
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Booth 2131

Leo Schwartz, ▲ Walter Bein, ▲ L. G. Burnell, Dave Launt, Dan Workman

SUBMINIATURE VARIABLE INDUCTORS—Smallest high Q Variable inductors for low frequency operation now available in all inductances up to 3 hy.

Burr-Brown Research Corp., Booth 3052
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Tucson, Ariz.

▲ Thomas R. Brown, ▲ R. Page Burr, ▲ John S. Anderegg, ▲ Howard Whitman, ▲ Alan Friedman, Alexander O. Levy, Jr.

New transistorized laboratory instruments. . . . * Model 200 Square Wave Generator, Model 100 AC Decade Amplifier. Highly portable long battery life transistorized apparatus.

Burroughs Corp.
6071 2nd Avenue
Detroit 32, Michigan

Booths 1718, 1720, 1722, 1724

A. P. Diamond

BURROUGHS



MAGNATRON BEAM SWITCHING TUBE

Optic Communications Equipment, Magnetic Cores, Digital & Analogue Computers, Tubes.

(Continued on page 162A)



Here, too, we make Nichrome*

Perhaps you didn't know that the world-famous alloy Nichrome is produced not only in The United States, but also in 6 Driver-Harris plants in England, Ireland, France, Italy, Austria, Spain, and in Canada by The B. Greening Wire Company. Also, Nichrome is a registered trade-mark in 55 nations.

At first, fifty-odd years ago, we manufactured electrical resistance alloys for furnace elements and domestic heating appliances only. Today we produce 132 different high nickel alloys in many different forms and in hundreds of sizes, for almost every kind of domestic and industrial application—of which Nichrome is the most illustrious.

Whenever you buy Nichrome, you are assured of the unsurpassed and unvarying *quality* which has made Nichrome the supreme world standard for electrical-resistance and heat-resistant alloys. This uniformly high quality, which we jealously guard as our most priceless possession, results from the technical excellence, the productive skill, and the quality controls the Driver-Harris craftsmen have gained in over 50 years of experience—and which are maintained with equal rigor in all Driver-Harris plants here and abroad. The result is a continuous benefit to the entire electrical, electronic, and heat-treating industries.

*T.M. Reg. U. S. Pat. Off.

Nichrome is made only by

Driver-Harris COMPANY HARRISON, NEW JERSEY

Manufacturing plants also in: ENGLAND • CANADA • IRELAND • FRANCE • ITALY • AUSTRIA • SPAIN

MAKERS OF THE MOST COMPLETE LINE OF ALLOYS FOR THE ELECTRICAL, ELECTRONIC, AND HEAT-TREATING INDUSTRIES

TWT LINE



24 types in production by the pioneer and leader in design and manufacture

(delivery: normally 4 to 6 weeks)

AMPLIFIERS

	Frequency, kmc					
	0.5-1	1-2	2-4	4-8	8-12	12-18
Broadband						
10 mw standard	x	x	x	x	x	
10 mw medium noise		x	x		x	
10 mw low noise		x			x	
1 watt standard			x	x	x	
Dispersive						
standard	x	x	x	x		
Backward Wave						
standard			x		x	

OSCILLATORS

>10 mw standard	x	x	x	x

Many special modifications of these tubes have been made to customer specifications. Inquire about your particular problems.

See these tubes and discuss your microwave power problems with us in Booths 3927 and 3929, IRE National Convention, New York.

Besides the industry's broadest line of traveling-wave tubes shown above, there are other types under development including different *frequency bands* as well as *p-m periodic focusing*. A technical staff is available for special research and development.

A comprehensive engineering handbook and catalog is waiting for your request. Write for your copy today.

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DEVELOPMENT
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ENGINEERS: If you are interested in electron devices and microwave techniques, why not consider sharing in our exponential growth? Submit resume to Dick Huggins.

HUGGINS LABORATORIES

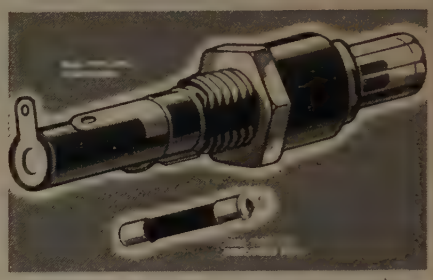
MENLO PARK 2 CALIFORNIA

Whom and What to See at the Radio Engineering Show

(Continued from page 160A)

Bussmann Mfg. Co.
University at Jefferson Sts.
St. Louis 7, Mo.
Booth 2739

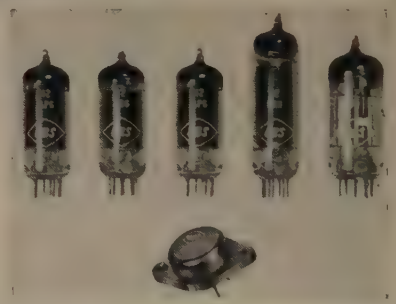
▲ L. E. Edwards, ▲ F. M. Sibley, ▲ C. Noss, ▲ A. H. Lucas, ▲ E. F. H. Revell, ▲ T. Lawless, ▲ C. J. Dane, ▲ E. E. Schelper, ▲ A. L. Branning



Fuses of all types for the protection of television, radio, instruments, controls, avionics and automobiles. Fusetron dual-element (slow-burning) fuses, fast acting fuses, to fit the most exacting requirements. Plus an accompanying line of fuse blocks and fuse holders.

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"Hybrid" auto radio tubes, transistors; Glass, plastic diodes; power, high-frequency, general-purpose transistors; silicon rectifiers; entertainment, military, industrial receiving, special-purpose, cathode-ray tubes.

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*AREMAC Oscilloscope Cameras featuring Polaroid backs, swing-away hoods, automatic sequential exposures. LABSCOPE Precision, Equal Amplifier DC-200kc general purpose oscilloscopes.

C & H Supply Co.
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Booth 4002

Harry Weir, Dan Heilpern, Don Ryan, James Colfer, Jack Hile.

Metal-Cal—The Original patented 003 anodized and dyed, etched aluminum foil identification.

(Continued on page 164A)

50 ohm Coax Terminations dc to 4 KMC!



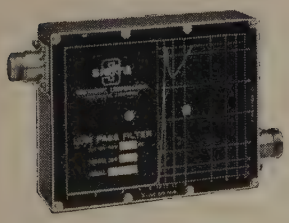
8 new instruments!
1 to 500 watts coverage!

New Sierra 160 series Coaxial Terminations are ideal for use with directional couplers, or in other applications requiring wide frequency range and low VSWR. They provide extremely high stability, and will dissipate full rated power continuously up to an ambient temperature of 40°C. Derating permits operating at still greater ambient temperatures. Terminations are completely shielded, and may be used to adjust transmitters without radiation. They are also useful for converting Sierra Bi-Directional Power Monitors to a termination type wattmeter.

SPECIFICATIONS

Model	Power*	Connectors	VSWR
160-1F 160-1M	1 watt 1 watt	Type N fem. Type N male	Less than 1.06, dc to 2 KMC; less than 1.08, dc to 4 KMC.
160-5F 160-5M	5 watts 5 watts	Type N fem. Type N male	Less than 1.08, dc to 4 KMC.
160-20F 160-20M	20 watts 20 watts	Type N fem. Type N male	Less than 1.08, dc to 1 KMC; less than 1.15, dc to 4 KMC.
160-100F	100 watts	Type N fem.	Less than 1.2, dc to 3300 MC.
160-500F	500 watts	Type N fem.	

*Up to 40° C ambient.



New LOW PASS FILTERS

Sierra 184 series Low Pass Filters have an insertion loss not more than 0.4 db in pass band, sharp cut-off, 1.5 VSWR or less, and rejection greater than 60 db from 1.25 to 10 times cut-off frequency. Five models: for cut-off frequencies of 44, 76, 135, 230, 400 MC. Power range 250 watts in pass band, 25 watts in rejection band.

Write for Bulletin!

Sierra Electronic Corporation

A Subsidiary of Philco Corporation

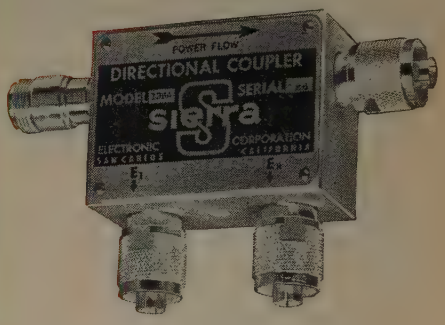
3885 Bohannon Dr., DAvenport 6-2060, Menlo Park, Cal., U.S.A.

Sales Representatives in major cities

CANADA: Atlas Radio Corp., Ltd., Toronto, Montreal, Vancouver, Winnipeg

EXPORT: Frazar & Hansen, Ltd., San Francisco, New York, Los Angeles

WIDEBAND DIRECTIONAL COUPLERS



Versatile, accurate Sierra couplers are offered in 6 models for frequencies 10 kc to 2000 mc. Couplers provide transmission line measurements including reflection coefficient, VSWR, power. Also permit matching of loads to lines dynamically by indicating conditions providing minimization of reflected voltages. Request Bulletins 101, 104.

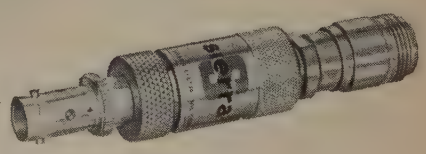
Coupling Factor: (in db ± 1 db)

Model	10 kc	3 mc	10 mc	30 mc	100 mc	300 mc	1000 mc	2000 mc
137, 137A				73	63	53	43	37
138, 138A				59	49	39	29	
145		52	42	32	22	12		
150				53	43	33	23	
139	50	50						

Directivity: 12 db ± 3 db greater than coupling factor at each frequency.

Impedance: Models 137 and 138 are 51.5 ohms. Models 137A, 138A, 145 and 150 are 50.0 ohms. Model 139 may be matched to most impedances.

Power: Usable to 1000 watts throughout frequency range.



SIERRA 148 CRYSTAL DETECTOR

Insures sensitive readout for Sierra Directional Couplers. Low VSWR, high sensitivity to 1200 MC. 50 ohm input impedance, filtered output. Type N input, BNC output connectors.

3663-R

Data subject to change without notice

AT LAST

a completely new kind of regulator!

ACTUALLY THREE REGULATORS IN ONE—*PLUS* MULTIPLE SENSING!

The APR 1010 combines many *new* regulation and sensing systems in one versatile package. Here's flexibility of operation never before possible...saves space, eliminates instrument duplication, means greater economy in engineering operations.



- **RMS VOLTAGE REGULATION**
- **AVERAGE REGULATION**
- **PEAK REGULATION**
- ***FIVE* PRINCIPAL SENSING ARRANGEMENTS**

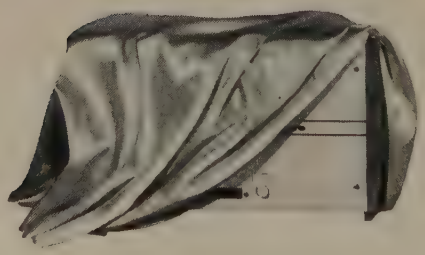
1. Internal 2. External 3. Remote 4. Constant Current 5. DC

ELECTRICAL CHARACTERISTICS:

Input	95-130 VAC, 1Ø (50 or 60 cps ±10%)
Output	115 VAC, adj. 110-120V
Regulation accuracy (RMS, average, or peak, switch selected)	±0.1% against line ±0.1% against load
Distortion	3% max.
Load	0-1000VA
P.F. range	Unity to 0.7 lagging
Recovery time	0.1 sec.

WRITE FOR COMPLETE TECHNICAL DATA.

See the new APR 1010 at Booths 2627-9 I.R.E. Show!



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SORENSEN & COMPANY, INC. • STAMFORD, CONN.

Whom and What to See at the Radio Engineering Show

(Continued from page 162A)

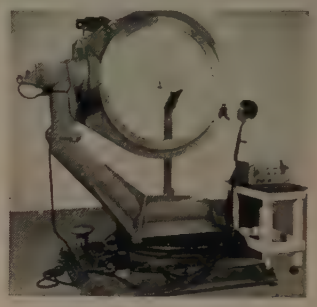
The Calidyne Co., Booths 3222, 3224
120 Cross Street
Winchester, Mass.

Thos. Gouzoule, Robert C. Lewis, Philip C. Efromson, Donald L. Wrisley, ▲ Lee Maserian, Edward Lavine, Hugh P. Maguire, ▲ Carl V. Segelstrom

1500 Pound Force Wide Band Shaker. Manufacturers of complete Integrated Vibration Systems for Environmental and Production Testing and Special Applications including Random, Complex, Wave, and Sinusoidal Testing.

California Technical Industries
Belmont, Calif.
Booth 3231

▲ J. M. Carter, ▲ E. J. Bradley, C. C. Trost



Radome Holding Fixture

RANDOM TESTING SYSTEM Microwave Antenna Pattern Equipment; Automatic Testing with the SUPERTESTER; new, wide range X-band SWEEP-FREQUENCY VSWR Measuring and Recording System; Flight and Altitude Simulators.

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Miniature Double-Tuned Shielded RF Coil Forms, Kollet Knobs, Printed Circuit Components, Coil Forms, Coils, Terminals, Capacitors, Panel and Chassis Hardware, Terminal Boards, Plugs, Jacks.

Camden Wire Co., Inc., Booth 4017
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Heavy Tinned Copper Wire and Strand; Wire for manufacture of Resistors, Strand as the conductor for hook-up wire.

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Arthur W. Fox, Bennett F. Becker, John M. Grinton, James E. O'Hara, J. Fred Dreher, Raymond Jensen

Miniaturized light weight 5F Series fastener featuring weight that offers new design possibilities to original equipment manufacturers.

Canadian Radium & Uranium Corp.
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Booth 4012

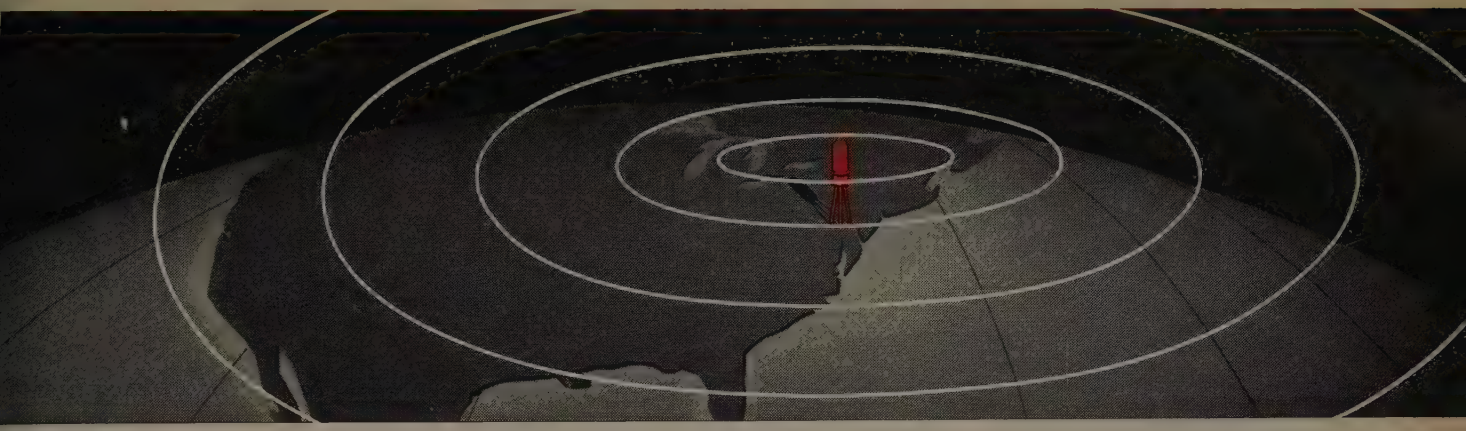
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"DUPLICAN"—The photo contact process for marking of convex, concave, irregular and flat surfaces.

ROLLER SCREENING—A new improved economical method of marking counter wheels spheres and drums.

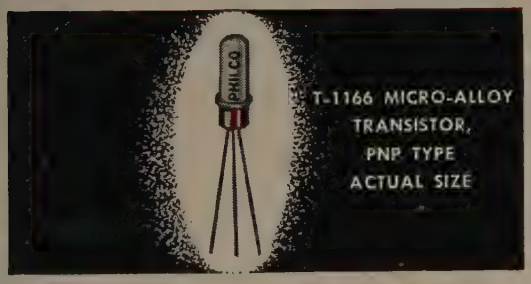
(Continued on page 166A)

F-l-a-s-h!...from Transistor Center, U.S.A.



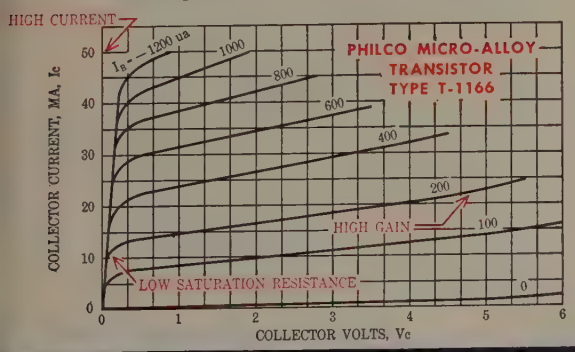
Announcing a new transistor class...

The PHILCO Micro-Alloy Transistor (MAT)*



CHECK THESE UNEQUALLED FEATURES

- **Excellent High Speed Switching characteristics.**
- **Low Saturation Voltage (low impedance)**
- **Excellent high frequency amplification.**
- **Excellent low-level amplifier over entire frequency range from D.C. to Megacycles.**
- **Exceptionally Long Life (hermetically sealed)**
- **Permits high speed computer design with Fewer Stages.**



...world's first production transistor with exceptionally high frequency and high gain . . . plus low saturation resistance!

This newest development from Philco Transistor Center features the characteristic high frequency response obtainable with extremely precise base width control. Designed for low voltage operation, the new MAT transistor is especially well suited for high speed applications where low saturation resistance (reduced power consumption) is necessary.

To combine high gain at high currents with high frequency response, the new MAT transistor employs a gallium doped alloy junction for the emitter electrode.

A special short-alloying cycle, combined with precise electro-chemical production techniques (pioneered and developed at Philco Transistor Center for production of SBT), results in the micro-alloy contact for exceptionally high injection efficiency. This new process assures higher gain, and permits operation at higher current. Beta linearity is excellent over the entire range of operating currents . . . up to 50 milliamperes.

● ***Write for complete information** and specifications. Make Philco your prime source of information for high frequency transistor applications.*

Visit The Unique Philco Transistor Display at IRE Show, New York Coliseum, March 18-21, Booth #1410, 1412, 1414.

**Patent Applied For*

PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

NOW AVAILABLE UP THROUGH 1 MEGOHM



WESTON VAMISTORS

Precision Metal Film Resistors

VISIT BOOTHS 2907-9 IRE SHOW

Weston Electrical Instrument Corp., Newark 12, N. J.

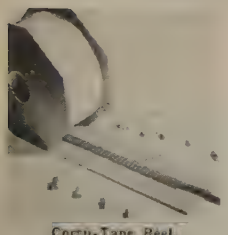
Now Pack Components *Automatically!*



Universal Taping Machine And Lead Straightener.

New Universal Taping Machine and Lead Straightener Does It!

- Fully automatic method of reel packing Axial Lead electronic components.
- Adaptable to lead taping or body taping.
- Adjustable for any body length or body diameter within limits of model design.
- Operates electrically and is equipped with variable speed control.
- Operates with or without interliner for lead protection.
- Tapes or straightens independently if desired.
- Accommodates pick-up reels up to 16" in diameter. Equipped with counter.
- Proven in production by Major Electronic Component producers and users.
- This machine with the Corru-Tape Reel is "The Complete Answer to all lead straightening and reel packing problems."



Corru-Tape Reel.

The Corru-Tape Reel—shown left—protects axial lead components from bending or jarring. This magazine type reel automatically releases the components.

For detailed information write today to:

PRESSURE SENSITIVE ENCLOSURES — DMCC industrial products

See The Universal Taping Machine And Lead Straightener in action. Visit our exhibit booth 4019. Fourth Floor—IRE Convention.

Whom and What to See at the Radio Engineering Show

(Continued from page 164A)

Cannon Electric Company
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Booths 2733-2737

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Miniature rack and panel connectors, miniature quick-disconnect connectors. Accessory to convert standard AN connectors for quick disconnect. Latest in guided missile connectors.

Capitol Machine Co., Booth 3839
36 Balmforth Ave.
Danbury, Conn.

Michael Baldasare, H. Frank Taylor, Arthur E. Wilson, Harry Varrelman, Bill Gorman, John Biernbaum, Wally Walworth, George Olmstead, Ted Felleisen, William McGary

Circuit Selector Switches, Push Button and Lever, Multiple and Single Position, Momentary and Locking, Illuminated and Non-Illuminated, Banked.

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Advanced research and development, microwave ferrite load isolators including miniaturization and broad banding * instrumentation for impedance measurements. Ferrite duplexers.

(Continued on page 170A)

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operate at +125 C ambient

for 1000 hours at full rated voltage

To help you solve difficult space problems in design functions demanding high reliability miniaturized equipment capable of operating in ambient temperatures ranging from —55C to +125C at full rated voltage, General Electric offers a variety of shapes and sizes of high temperature Tantalytic capacitors.

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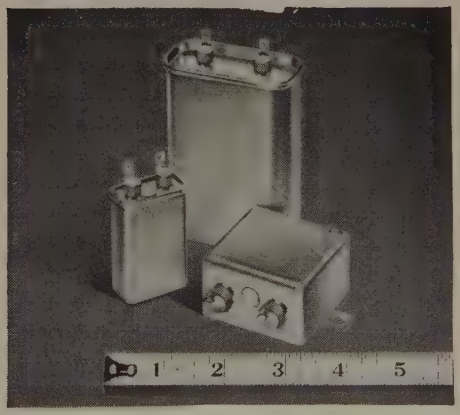
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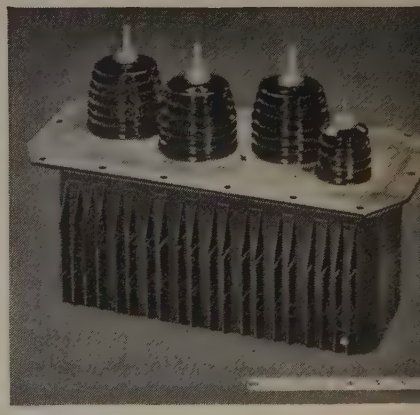
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NEWS for design engineers



ACTUAL SIZE

UNION

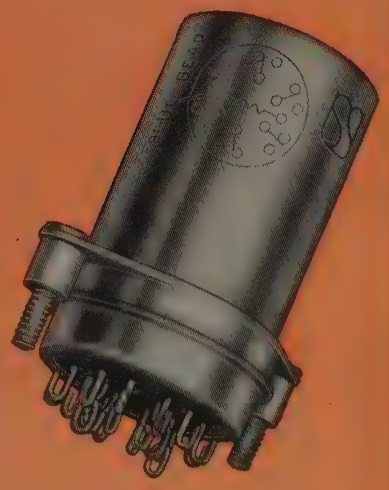
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Whom and What to See at the Radio Engineering Show

(Continued from page 166A)

Century Electronics & Instruments, Inc., Booths 3211-3213
1333 North Utica St., Box 6216
Tulsa, Okla.

T. J. Ray, Jr.

Oscillographs, galvanometers.

The Ceramaseal Company, Booth 4013
Box 25,
New Lebanon Center, N. Y.

Herbert A. Omley, Paul Ost, Gustav Lind, Gene D. Sawin

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Chassis-Trak ultra thin slides (.350 thick) now have solid rollers incorporated for additional ease of operation to service both circuitry and tubes.

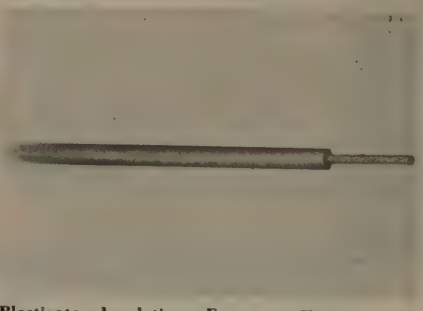
Chatham Electronics, Div. of Gera Corporation, Booths 2833-2837
630 Mt. Pleasant Ave.
Livingston, N. J.

▲ Benjamin F. Steiger, Max Yarmovsky, Ward W. Watrous, ▲ David M. Sanger, Robert Kessler, Warren Master

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Plasticote Insulation Features Chester Construction

New wire and cable construction for commercial and military applications featuring rugged Plasticord and Plasticote insulations. Included are hook-up wires, coaxial cables and miniature types.

(Continued on page 178A)

* Indicates new product.
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Display your badge with your name very prominently. Even your competitors will welcome you. Everybody is important to every exhibitor. Help him to know who you are so he can serve you better. By reading your badge he can more swiftly estimate what will interest you and show it to you.

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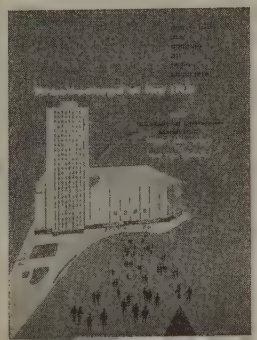
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THE COVER—The newly opened New York Coliseum will be the scene this month of the largest technical exhibition ever held, as the IRE National Convention gets under way on March 18. All four floors of the huge building will be used to house the latest products and most important developments of some 840 electronics firms. Technical sessions will be held at both the Coliseum and the nearby Waldorf-Astoria Hotel. Full details concerning the technical program start on page 371, and a list of exhibitors and their products appears in the advertising section of this issue.

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Raymond A. Heising

WINNER OF THE 1957 FOUNDERS AWARD

Raymond A. Heising was born August 10, 1888, at Albert Lea, Minn. He received a degree in electrical engineering from the University of North Dakota in 1912 and the master's degree from the University of Wisconsin in 1914.

From 1914 until his retirement in 1953, Dr. Heising was associated with the Western Electric Company and Bell Telephone Laboratories. He played a major role in the development of radiotelephone systems for military use in World War I, and for transoceanic and ship-to-shore public service use. He also conducted much research work on ultra-short waves, electronics and piezoelectric crystal devices. He invented several modulation systems which are still in wide use today: the constant potential system, the grid modulation system for radio, the rectifier modulation system used in carrier telephony, and in particular, the constant-current or Heising modulation system. He has over one hundred United States patents, including the patents on the Class C amplifier and diode-triode detector amplifier circuit, and has published numerous technical papers in engineering journals.

Since 1953 Dr. Heising has been engaged as an independent consulting engineer and patent agent.

He is a Fellow of the American Institute of Electrical Engineers and American Physical Society. He was awarded the Modern Pioneer Award from the National Association of Manufacturers in 1940. He received an honorary Doctor of Science degree from the University of North Dakota in 1947, and the Armstrong Medal from the Radio Club of America in 1954.

An Associate of the IRE since 1920 and winner of the Morris Liebmann Memorial Prize in 1921, he became a Fellow in 1923. He served as IRE President in 1939, Treasurer from 1943 to 1945, and as an elected member of the Board of Directors for seventeen years. He was chairman of numerous IRE committees, among them the committees on Sections, Professional Groups and Office Quarters.

Dr. Heising will receive the IRE Founders Award, an award which is given only on special occasions to outstanding leaders in the radio industry, at the banquet of the annual IRE National Convention this month. The award is being bestowed upon him "for his leadership in Institute affairs, for his contributions to the establishment of the permanent IRE Headquarters, and for originating the Professional Group system."



Julius A. Stratton

WINNER OF THE 1957 MEDAL OF HONOR

Born at Seattle, Wash. in 1901, Julius A. Stratton attended the University of Washington for one year until he came to the Massachusetts Institute of Technology to obtain his bachelor's degree in 1923 and master's degree in 1925. He then did graduate study in Grenoble and Toulouse, France, and the Technische Hochschule of Zurich, Switzerland, awarded him the degree of Doctor of Science in 1927. During the following year he studied under a traveling scholarship from M.I.T., chiefly at Munich and Leipzig, Germany.

Dr. Stratton joined the staff of M.I.T. in 1928 to serve in the electrical engineering and physics departments for twenty years. In 1945 he was appointed Director of the Research Laboratory of Electronics. He was named Provost of M.I.T. in 1949, and in 1951 he became vice-president as well. Last year he was named to the newly-created post of Chancellor. As Chancellor, Dr. Stratton administers the academic program of the institution, acts as deputy to the president, and serves as general executive officer.

During World War II he served as Expert Consultant in the Office of the Secretary of War, and was awarded its Medal for Merit in 1946.

He is a Fellow of the American Institute of Physics and the American Academy of Arts and Sciences, and a member of the American Philosophical Society, the National Academy of Sciences, Tau Beta Pi, and Sigma Xi. He is an appointed trustee of the Ford Foundation, and one of the nine-member National Science Board of the National Science Foundation.

Dr. Stratton is the author of numerous technical papers and books on theoretical physics, especially electromagnetic theory. His many activities include membership on the Defense Science Board, the National Science Foundation Advisory Committee on Government-University Relations, and the Naval Research Advisory Committee.

He became an IRE Member in 1942, a Senior Member in 1943, and a Fellow in 1945. He served on the Board of Directors from 1948–1951, and again in 1954. He headed the Radio Wave Propagation and Utilization Technical Committee from 1945 to 1948.

Dr. Stratton will receive the Medal of Honor, IRE's highest technical award at the convention banquet this month "for his inspiring leadership and outstanding contributions to the development of radio engineering as a teacher, physicist, engineer, author and administrator."

Scanning the Issue

On the Statistics of Individual Variations of Productivity in Research Laboratories (Shockley, p. 279)—A novel statistical study has been made of the large differences in scientific creativity that exist between individual research workers. The author uses as his yardstick the number of publications that an individual has made, showing first that for the purposes of this study this is a surprisingly accurate method of measuring scientific productivity. A study of the publication rates of individuals in a number of research laboratories reveals that the variations in productivity are exponential in character. The author explains this phenomenon on the basis of simplified models of the mental processes concerned. For example, the man who can grasp and relate five ideas at the same time is probably capable of producing a great many more inventions than the man who can grasp only four ideas. Thus a small change in certain factors of the mental process can result in a very large change in output. The study closes with an examination of the relationship between salary and productivity which leads to some important conclusions regarding the effect which the present limits on government salaries is having on the originality and leadership available in government laboratories.

Molecular Amplification and Generation of Microwaves (Wittke, p. 291)—Continuing its series of invited review papers, the PROCEEDINGS presents this month a discussion of a radically different method of generating and amplifying microwaves which has greatly excited the interest of scientists during the last two or three years. This new method, which is still in the early stages of development, makes use of the internal energy of molecules rather than the movement of charged particles as a source of rf energy, and opens the door to a whole new class of gaseous and solid-state microwave devices. The operation of these devices is tied to the fact that the internal energy systems of molecules exist in several distinct energy states. Upon exposure to a microwave field of the right frequency, a molecule in a lower energy state may jump to a higher energy state, absorbing energy from the field in the process. More important, a high-level molecule may drop to a lower energy level and give up some of its internal energy. Under normal circumstances, all molecular systems have a predominance of low-level molecules, and thus are absorptive. Hence the problem of building a molecular amplifier is one of first creating an "unnatural" condition in which the high-level molecules predominate and then inducing them to give up some of their energy. The several methods thus far proposed for accomplishing this, and the underlying physical principles involved, are the subject of this thorough and well-written discussion. The timeliness of this article is attested to by the fact that just one month ago a leading laboratory announced the first successful operation of a solid-state microwave oscillator utilizing these new principles. As further progress is made, we can look forward to new devices which, among other things, will provide us with extremely low noise amplification for communications and radio astronomy applications, super-stable oscillators for frequency standards, and a promising method of generating frequencies in the millimeter and submillimeter range.

The Spacistor, A New Class of High-Frequency Semiconductor Devices (Statz and Pucel, p. 317)—A new approach is suggested for extending the useful frequency range of semiconductor devices into the microwave region. The relatively slow diffusion of minority carriers through the almost field-free regions of the base is an important frequency-limiting factor in present devices. In the new class of devices proposed here, electrons or holes are injected directly into space-charge regions, and the slow-diffusion areas are thus avoided. The spacistor is characterized by junctions which are reverse-biased at voltages high enough for the injected carriers to be multiplied by the avalanche process. The principles, problems and suggested solutions presented here lay important groundwork for the development of higher frequency semiconductor devices.

Ferrite Apertured Plate for Random Access Memory (Rajchman, p. 325)—A simple method of fabricating a plate containing a large array of memory cells has been developed that promises to greatly increase the storage capacity of even the largest present-day digital memory systems. The plate, which is made of nonconducting ferrite material, is molded with an array of holes in it and is then coated with a conductive pattern to form a printed winding linking all holes in series. Large stacks of these plates can be readily wired together to form an easily assembled large-scale memory. This is a major improvement over current laborious methods of assembling memory cells individually, and opens possibilities of memories with capacities of millions of bits.

Stability and Power Gain of Transistor Amplifiers (Stern, p. 335)—This paper offers the practicing engineer a new and practical measure of the maximum realizable stable power gain of a transistor amplifier that operates at frequencies where it could become unstable. The clarity of the presentation, as well as the importance of the contribution, will make this work of general interest to practically all people who design any but audio frequency types of transistor amplifiers. The results and point of view are interesting also for the cases of very-high-frequency triode tube amplifiers, where the same sort of problems arise and where the analysis presented applies equally well.

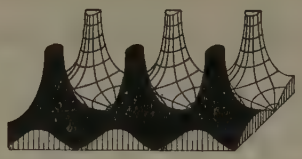
Ferriod Radiator System (Reggia, et al, p. 344)—The dielectric, magnetic and polarization characteristics of ferrites have been brought together in this paper to perform a variety of useful functions in a microwave antenna system. The radiating elements consist of dielectric rods made of ferrite, which are shaped to give maximum radiation along the axis of the rods and minimum radiated power in the side lobes. Ferrite-loaded cavities and waveguides are used for a number of switching and coupling schemes, including devices for beam lobing and array scanning. The small size of these systems will make them very useful in reducing the size of microwave antenna systems, a matter of considerable importance, for example, in portable radars.

IRE Standards on Piezoelectric Crystals—The Piezoelectric Vibrator: Definitions and Methods of Measurement (p. 353)—The IRE Committee on Piezoelectric Crystals has produced a timely and useful Standard that specifies the nomenclature and a practical method of measuring the various quantities associated with piezoelectric vibrators.

IRE National Convention Program (p. 371)—A program is given of the Convention activities and abstracts of the 284 papers which will be presented on the 18th through the 21st of this month at the New York Coliseum and Waldorf-Astoria Hotel.

Whom and What to See at the Radio Engineering Show (p. 110A)—A full list of the 840 Convention exhibitors, booth numbers and personnel, and products that you will meet and see on March 18–21 at the New York Coliseum is given, with floor plans showing booth locations.

Poles and Zeros



Big Step. On January 4th last, the Board of Directors by unanimous vote set in motion the IRE Group Affiliate Plan. This plan, originally proposed by Editor Emeritus A. N. Goldsmith, permits members of other professional societies to participate as individuals in Professional Group activities and to receive PG TRANSACTIONS without prior admission to IRE membership. The details of the Affiliate Plan are presented on page 278 of this issue by W. R. G. Baker, Chairman of the Professional Groups Committee.

This is a big step for the IRE, certainly its most important action since the founding of the Professional Group system. The proposal was debated for months before its approval by the Board because, as Dr. Baker points out, the Affiliate Plan carries with it the risk that Affiliate status may be elected by some specialists who, in good conscience, should become IRE members.

The Plan has been worked out to minimize this risk. For example, no one who has been an IRE member during the five years prior to his application will be admitted as an Affiliate. The risk is thus confined to the future, but it is possible that the growth of IRE membership may be diminished if Affiliate status is more attractive than IRE membership to any substantial number of potential members.

We predict that no such trend will develop, that, in fact, more members will be attracted to full membership in the IRE through initial exposure as Group Affiliates than will be lost. Such a counter-trend can be expected to appear if three prerequisites are met. First, it depends on the continued conviction of IRE members, particularly those active in PG affairs, that the parent IRE serves a purpose and provides services which transcend individual specialties—a conviction that the IRE is, and must continue to be, more than a mere holding company for Professional Group assets. Second, it depends on recognition by technical workers generally that over-specialization is dangerous, that lack of interest in other fields marks a sterile intellect, and is injurious to the man and his profession.

Third, as a matter of hard practicality, it depends on value received. According to the present rules, Group Affiliate status in the majority of the Groups costs $6.50 per year. IRE membership costs $10.00 the first three years and $15.00 thereafter. What does the IRE member get for the difference? He gets the privilege of holding office but this affects few members since there are less than 500 elective and appointive offices in the Sections, Groups and national organization. The privilege of holding office is real, but it is not a compelling influence.

The big difference is the PROCEEDINGS. Members receive it. Affiliates do not. Affiliates will apply for full membership, by and large, because they want to read the PROCEEDINGS. This is the challenge which the Affiliate Plan presents to the Editorial Board, its heirs and assigns. With the help of all concerned, we aim to meet it.

Back Issues. One of the many incidental useful services performed by the editorial staff is bringing together those who have back issues of IRE publications to dispose of and those who wish to acquire same. If you have back issues to offer, two courses of action are open: (1) we will send you a list of dealers in second-hand technical periodicals who may, if the collection is complete and goes back a number of years, offer you a modest sum and pay the freight into the bargain; or (2) if such negotiations come to naught, the Institute may take your back issues off your hands if they are in short supply, but will limit its outlay to the transportation charges to IRE Headquarters in New York. If you elect the latter option, please communicate your intentions to IRE before shipping, describing your collection and its condition. HQ will respond promptly with shipping instructions or will suggest other means of disposal.

If you are on the acquisition side of the brokerage, write stating your needs. Back issues from our regular stock will be sold to you at the established prices. If you prefer, or if we are out of stock, we will send the list of second-hand dealers, and you take it from there.

Incidental intelligence: the back-issue demand displays a pronounced peak 17 years after the date of issue. From this we deduce that patent searchers, hoping to find an anticipation of an issued patent (which expires in 17 years), are among our best customers.

Meetings. Members who wonder whether the two mansions the IRE occupies as Headquarters are useful as well as ornamental will be reassured by the fact that, during the 260 working days of 1956, no fewer than 391 committee meetings were held at Numbers 1 and 5, East 79th Street.

The IRE "Affiliate" Plan—A New Venture in Engineering Society Structure and Service

W. R. G. BAKER, *Chairman*
IRE Professional Groups Committee

On January 4, 1957 the IRE Board of Directors arrived at a decision which may in time prove to be one of the most far-reaching in its 45-year history. On that date the Board adopted a plan which will enable non-IRE members whose main professional interests lie outside the sphere of IRE activities to become affiliated with certain of the IRE Professional Groups *without* first having to join the IRE itself.

This plan is aimed at those specialists in other fields of science and technology whose work touches upon our own electronics and communications field only in specialized areas. In effect, the IRE is extending the specialized services of its Professional Groups to every field of science and engineering.

An outstanding example of where these services are needed may be found in the case of the medical and biological sciences. At the present time some 1400 IRE members enjoy the privileges of membership in the Professional Group on Medical Electronics. And yet there are hundreds, perhaps thousands, of medical doctors, biologists, and others to whom the activities of this Group would be of interest and value. Both they and the Group would benefit from their participation. To require these persons, who have no interest in radio engineering, to join the IRE in order to join the Group is unreasonable, and probably futile as well. In fact, it was largely to provide an answer to this particular problem that the Affiliate Plan was first conceived, although it pertains to other fields as well, such as Computers, *etc.*

The Affiliate Plan is admittedly an experiment. So far as is known, no other society has ever tried a similar scheme. The Board of Directors feels strongly that the benefits afforded by the plan justify the risk that some persons who should join the IRE will instead become Affiliates. To minimize this risk, the plan has been carefully worked out along the following lines:

1) Participation in the plan is at the option of each Professional Group. It is not expected that all Groups will adopt it; only those which feel it serves a need in their particular field.

2) Each Group interested in initiating the Affiliate Plan must submit to the Chairman of the Professional Groups Committee a list of accredited organizations which has been selected and approved by its Administrative Committee, for official approval by the IRE Executive Committee.

3) To be an Affiliate of a Professional Group, a person must belong to an accredited organization approved by that Group and the IRE Executive Committee. Moreover, he shall not have been an IRE member during the five years prior to his application. He may affiliate with more than one Group, provided the accredited organization to which he belongs is recognized by the Groups concerned.

4) The fee for Affiliates shall be the assessment fee of the Group, plus $4.50. The latter covers IRE subsidies to the Group, Professional Group overhead expenses borne by IRE Headquarters, and 50 cents which is to be rebated to IRE Sections for mailing and meeting costs.

5) An Affiliate will be entitled to receive the TRANSACTIONS of his Group and that part of the IRE National Convention Record pertaining to his Group. He will be eligible for a Group award, and may attend local or national meetings of the Group by payment of charges assessed Group members.

6) An Affiliate cannot serve in an elective office in the Group or Group Chapter, nor vote for candidates for these offices.

7) An Affiliate may hold an appointive office in the Group or Group Chapter.

8) An Affiliate may not receive any IRE benefits that are derived through IRE membership.

The Affiliate Plan is a bold and farsighted venture; one that recognizes and provides for the rapidly spreading influence of electronics in every walk of scientific and technological life, and one that enables the IRE to further its aims as a professional engineering society—the advancement of radio engineering and related fields of engineering and science.

On the Statistics of Individual Variations of Productivity in Research Laboratories*

WILLIAM SHOCKLEY†, FELLOW, IRE

In the following pages a co-winner of the 1956 Nobel Prize in Physics presents a novel study of one of today's most precious commodities—scientific productivity. The author not only measures the variations that exist between different research workers, he also explains these differences and draws some specific conclusions about the relationship of salary to productivity. PROCEEDINGS readers will find this an especially timely and significant discussion, particularly in view of the present widespread concern about manpower shortages and proper utilization of scientific personnel.—*The Editor*

Summary—**It is well-known that some workers in scientific research laboratories are enormously more creative than others. If the number of scientific publications is used as a measure of productivity, it is found that some individuals create new science at a rate at least fifty times greater than others. Thus differences in rates of scientific production are much bigger than differences in the rates of performing simpler acts, such as the rate of running the mile, or the number of words a man can speak per minute.**

On the basis of statistical studies of rates of publication, it is found that it is more appropriate to consider not simply the rate of publication but its logarithm. The logarithm appears to have a normal distribution over the population of typical research laboratories. The existence of a "log-normal distribution" suggests that the logarithm of the rate of production is a manifestation of some fairly fundamental mental attribute. The great variation in rate of production from one individual to another can be explained on the basis of simplified models of the mental processes concerned. The common feature in the models is that a large number of factors are involved so that small changes in each, all in the same direction, may result in a very large change in output. For example, the number of ideas a scientist can bring into awareness at one time may control his ability to make an invention and his rate of invention may increase very rapidly with this number.

A study of the relationship of salary to productivity shows that rewards do not keep pace with increasing production. To win a 10 per cent raise a research worker must increase his output between 30 and 50 per cent. This fact may account for the difficulty of obtaining efficient operation in many government laboratories in which top pay is low compared to industry with the result that very few highly creative individuals are retained.

I. INTRODUCTION

EVERYONE who has been associated with scientific research knows that between one research worker and another there are very large differences in the rate of production of new scientific material. Scientific productivity is difficult to study quantitatively, however, and relatively little has been established about its statistics. In this article, the measure of scientific production I have used is the number of publications that an individual has made.

The use of the number of publications as a measure of production requires some justification. Most scientists know individuals who publish large numbers of trivial findings as rapidly as possible. Conversely, a few outstanding contributors publish very little. The existence of such wide variations tends to raise a doubt about the appropriateness of quantity of publication as a measure of true scientific productivity. Actually, studies quoted below demonstrate a surprisingly close correlation between quantity of scientific production and the achievement of eminence as a contributor to the scientific field.

The relationship between quantity of production and scientific recognition has been studied recently by Dennis,[1] who considered a number of scientists who have been recognized as outstanding. As a criterion of eminence for American scientists, he has used election to the National Academy of Sciences; his study is based on 71 members of the National Academy of Sciences who lived to an age of 70 or greater and whose biographies are contained in the Biographical Memoirs of the Academy. He finds that all of these people have been substantial contributors to literature with the range of publications extending from 768 to 27, the median value being 145. (Based on a productive life of approximately 30 years, this corresponds to an average rate of publication of about 5 per year, a number to which I shall refer in later parts of this discussion.) Dennis concludes that relatively high numbers of publications are characteristic of members of the National Academy of Sciences. He conjectures that of those who have achieved the lesser eminence of being listed in American Men of Science, only about 10 per cent will have a

* Original manuscript received by the IRE, December 3, 1956. Presented first as the invited lecture, Operations Res. Soc. of Amer., Washington, D. C., November 19, 1954; also at the Washington Phil. Soc., late spring, 1955; and at the 1955 fall meeting of the Natl. Acad. of Science. It has been reported briefly in *Newsweek*, December 6, 1954; *Chem. Week*, November 26, 1955; abstracted in *Science*, December 10, 1955; and in *Science Digest;* February, 1955.

† Shockley Semiconductor Lab. of Beckman Instr., Inc., Mountain View, Calif. This material was prepared while the author was Deputy Director and Res. Director of the Weapons Systems Evaluation Group, Dept. of Defense, on leave from Bell Telephone Labs., Inc.

[1] Wayne Dennis, "Bibliography of eminent scientists," *Sci. Monthly*, vol. 79, pp. 180–183; September, 1954.

publication record exceeding the 27; which represents the minimum publisher of the 71 listed in Biographical Memoirs of the National Academy of Sciences. He has also studied eminent European scientists and comes to essentially the same conclusion. In fact his study goes further and shows that almost without exception heavy scientific publishers have also achieved eminence by being listed in the Encyclopedia Britannica or in histories of important developments of the sciences to which they contributed.

It should be remarked that in Dennis' work, he includes more routine types of contributions (such as popular articles) than are generally associated with scientific eminence. However, it may still be appropriate to quote a few of the statistics obtained by Dennis for people who certainly classify in the genius class of the scientific publishers. Among these Dennis refers to: Pasteur with 172 publications, Faraday with 161, Poisson with 158, Agassiz with 153, Gay-Lussac with 134, Gauss with 123, Kelvin with 114, Maxwell with 90, Joule with 89, Davy with 86, Helmholtz with 86, Lyell with 76, Hamilton with 71, Darwin with 61, and Riemann with 19. Riemann, who was the least productive, died at the age of 40. At his rate of publication, he would probably have contributed at least another 10 or 20 publications had he lived to the age of 70. Even with 19, he was in the top 25 per cent of the 19th century scientists referred to in Dennis' study.

The chief conclusion reached in this article is that in any large and reasonably homogeneous laboratory, such as, for example, the Los Alamos Scientific Laboratory and the research staff of the Brookhaven National Laboratory, which are included in this study, there are great variations in the output of publication between one individual and another. The most straightforward way to study these variations is to list the number of individuals with zero, one, two, etc., numbers of publications in the period studied. This compilation may then be plotted as a distribution graph [see Fig. 2(b) for an example]. In some cases, however, the data are too meager for a smooth trend to be seen easily and another form of presenting the data is more convenient.

The form used for most of the data presented in this paper is the *cumulative distribution graph*.

Such a graph can be illustrated in terms of the distribution of the height of a regiment of men. If the men are lined up in order of increasing height at a uniform spacing, then, as shown in Fig. 1(a), there will be a steady increase in height from the shortest man to the tallest man. There will usually be a few men who are exceptionally short, a few men who are exceptionally tall. For the majority of the men the height will vary relatively uniformly along the line of the men. In general, one should thus expect an S-shaped curve with an inflection point near the middle of the distribution.

Such a curve is closely related to the distribution in height shown in Fig. 1(b), which represents the number of men whose height lies in any particular interval of height. This can be obtained from Fig. 1(a), as is represented there, by drawing two lines bracketing a certain interval in height and counting the number of men lying in this range. Fig. 1(b) represents a smooth curve drawn through such a distribution. It can, in fact, be obtained from Fig. 1(a) by drawing a smooth curve through the distribution in height and differentiating the number of men as a function of the height.

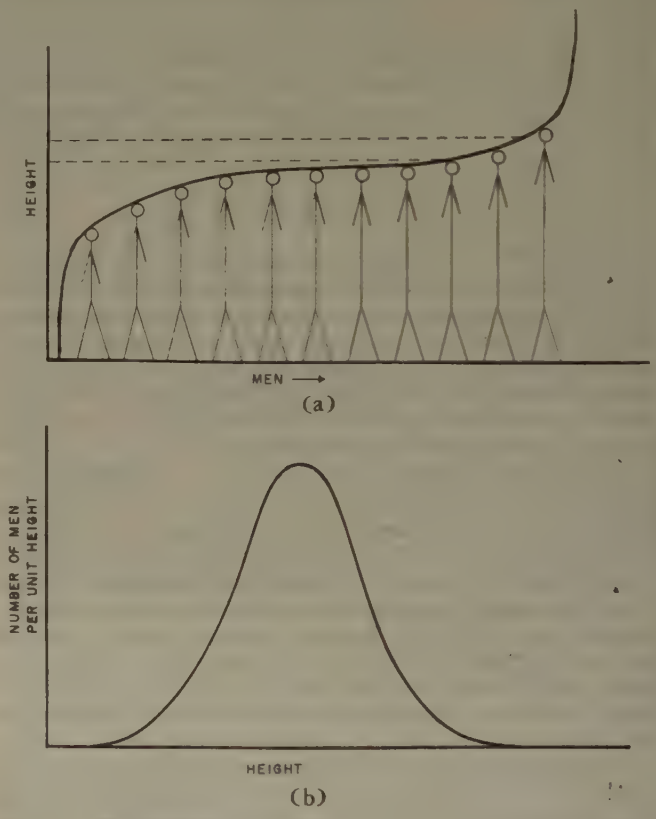


Fig. 1—The cumulative-distribution graph and the normal-distribution curve. (a) The cumulative-distribution graph represented by men arranged in order of height at uniform spacing. (b) A "smoothed" distribution curve, of normal form, such as might be obtained from (a) by finding the number of men in each small increment of height.

For many natural phenomena and in particular for those in which the measured quantity varies due to the additive effects of a large number of independently varying factors of comparable importance, a Gaussian or normal distribution, like that of Fig. 1(b), is obtained. Conversely, if distribution is normal, then the cumulative distribution graph will have the symmetrical S-shaped characteristic in Fig. 1(a), the middle flat portion corresponding to large numbers of cases in the central range, and the rapid convergence of the extremes to their asymptotes corresponding to the scarcity of cases which deviate much from the mean value.

One of the new results of this study, presented below in Section IV, is that the data on rates of publication can be well represented by a normal distribution when treated in a certain fashion. Some possible explanations for this observation are discussed in Section VI.

II. A Study of Publication Records

As a first example, I shall discuss the statistics of the publications of a group of people in the Los Alamos Scientific Laboratory. This sample of approximately 160 people was selected on the basis that the individuals were professionally mature and located in laboratories whose activities are of such a nature that there is some probability that workers in them might contribute to a physical or electrical engineering publication. Such publications are abstracted in *Science Abstracts A* and *B*, respectively. The publication record for each individual was ascertained by looking through the author index of *Science Abstracts* for the years 1950 to 1953, inclusive.

From these data, a cumulative-distribution graph constructed like that shown in Fig. 1(a) is obtained by listing the men in order of their publications. It is found that approximately half of the individuals have no publications at all. Then there are about 30 individuals with one publication, 20 individuals with two publications and so on. The cumulative-distribution curve shown in Fig. 2(a) has little resemblance to the simple S-shaped curve shown in Fig. 1(a). For one thing it is concave upwards throughout. For another it shows too many individuals with publication rates higher than seven in four years compared to the shape of the curve up to that rate. The distribution curve, shown in Fig. 2(b), is not normal, but instead is essentially hyperbolic in form.

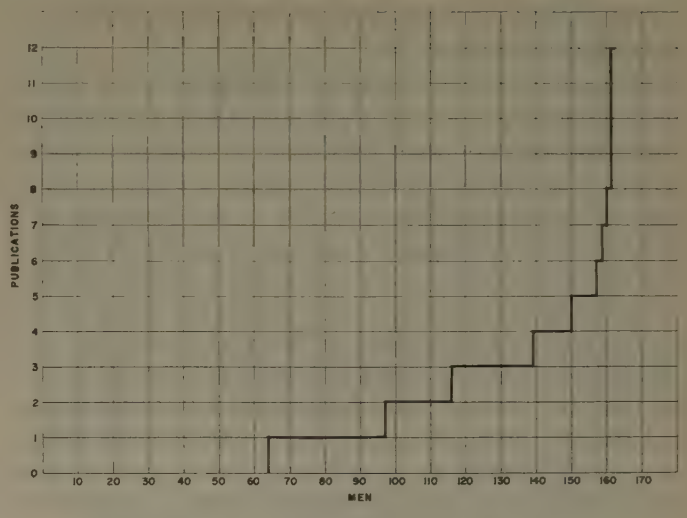
Replotting this same data in Fig. 3 on a logarithmic scale for the number of publications results in a line which does look much more like a portion of the cumulative-distribution graph for a normal distribution. The line is not a smooth curve, of course, but rises in steps. However, a smooth curve drawn through the steps has an approximately linear portion, corresponding to the linear portion of Fig. 1(a), followed by an abrupt turn up at the high end corresponding to the relatively small number of people who on the logarithmic scale have exceptionally large rates of publication.

It is one of the chief conclusions of this study that the more or less normal distribution of the logarithm of rate of publication is characteristic of the statistics of the scientific creative process. Perhaps the most important feature of this conclusion is that the rate of publication increases approximately exponentially from individual to individual, taken in order of increasing rate, and that the differences in rate between low and high producers are very large. The conclusion that the exponential character of the distribution is fundamental to the creative process gains support from the fact that certain other hypotheses intended to explain it as some sort of artifact can be examined and rejected.

In subsequent sections we shall refer to the normal distribution of the logarithm as *log-normal distribution*.

III. Some Basic Data on Rates of Publication

One of the first hypotheses called the "organization hypotheses" put forward to explain how the log-normal



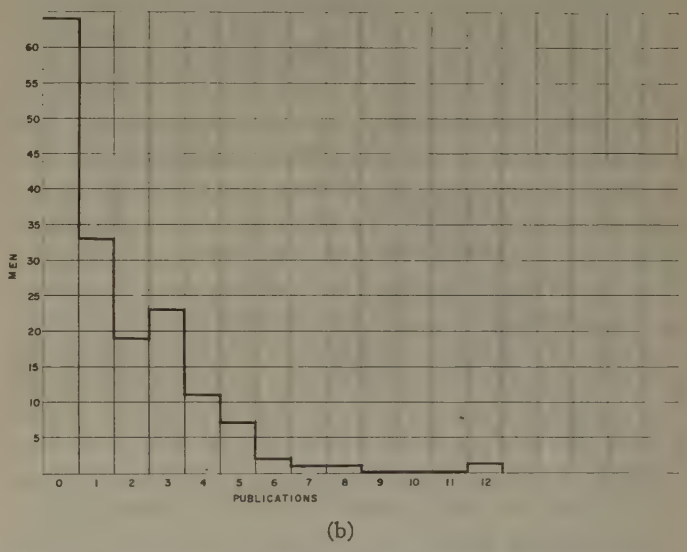


Fig. 2—Distribution of rate of publication (number of entries in *Science Abstracts A and B* in four years) at Los Alamos. (a) Cumulative distribution. (b) Distribution (number of men with each rate of publication).

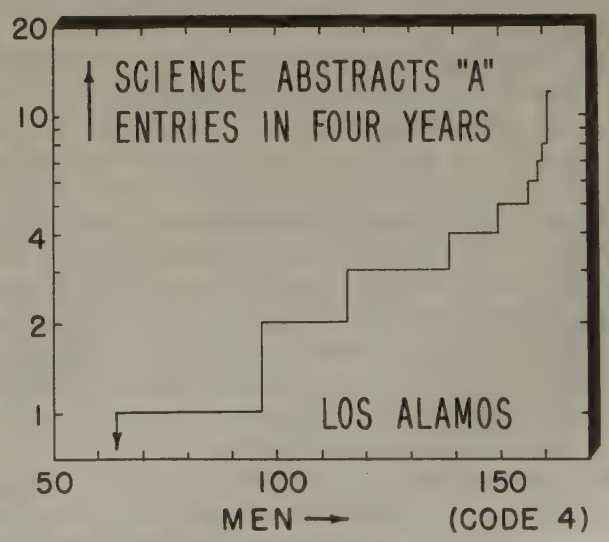


Fig. 3—Cumulative distribution on logarithmic scale for number of publications at Los Alamos.

distribution arises was that it is a consequence of the organization of research activities in large, modern laboratories. In such laboratories, physical scientists frequently make use of very complicated apparatus and large nuclear machines. As a result of this collaborative effort they frequently publish papers jointly, the number of authors varying from two to five or six in ordinary cases. The "organization hypothesis" endeavors to use joint authorship to explain the exponential character as follows: As a consequence of the size of the teams who work together, an individual who has some supervisory or organizational responsibility may contribute to the activities of many men and be listed as a co-author on many papers. As a result, a relatively few people will appear as co-authors of a very large number of papers and this group can be better included in a log-normal distribution than in a normal distribution.

This "organizational hypothesis" can be disposed of by several arguments, some of which are quite instructive. One of these arguments is based on the observation that the exponential aspects of the cumulative-distribution graph is independent of the particular organizational features of the laboratory considered and is a general characteristic of all laboratories studied in this article. For example, the organizational situation in some of the laboratories of the National Bureau of Standards would not lead to large numbers of publications by supervisors. For one Division of the National Bureau of Standards, records were available of the total number of publications and patents made by the individuals in this Division during a period of several years. These data are shown in Fig. 4. It is seen from this figure that the data lie on a relatively smooth exponentially increasing trend followed by a rapid turn-up corresponding again to a few individuals with exceptionally high publication records. Since the organization of activities is quite different in the Bureau of Standards from what it is at Los Alamos while the distribution curve is the same, the "organizational hypothesis" can be discarded.

The "organizational hypothesis" can also be rejected by studying the effect of joint authorship on the distribution of rate of publication. We shall illustrate this argument using data from the Brookhaven National Laboratory. There are approximately 180 members of the research staff of the Brookhaven National Laboratory. The "total" number of entries plotted as a cumulative distribution for these people is shown as the line marked "total" in Fig. 5. Since Brookhaven operates in a fashion rather similar to Los Alamos, it might be expected that the "organizational hypothesis" would apply equally well here. In order to test this, two other lines have been constructed on Fig. 5.

The bottom line, marked "solo," has been obtained by discarding all publications having more than one author. It is seen that a relatively small fraction of the people have made "solo" publications. However, it should be noted that the most prolific publishers of these

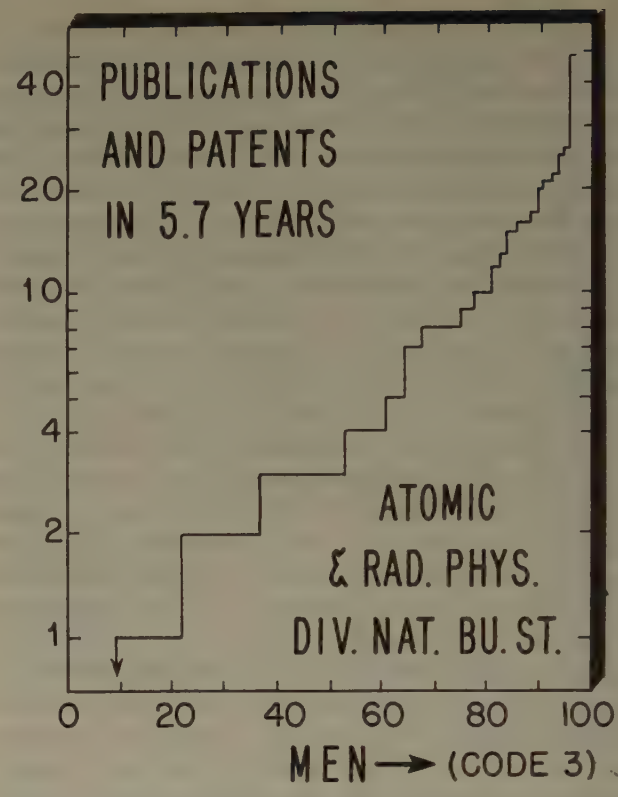


Fig. 4—Cumulative distribution on logarithmic scale for publications and patents for Atomic and Radiation Physics Div., National Bureau of Standards, for a period of 5.7 years.

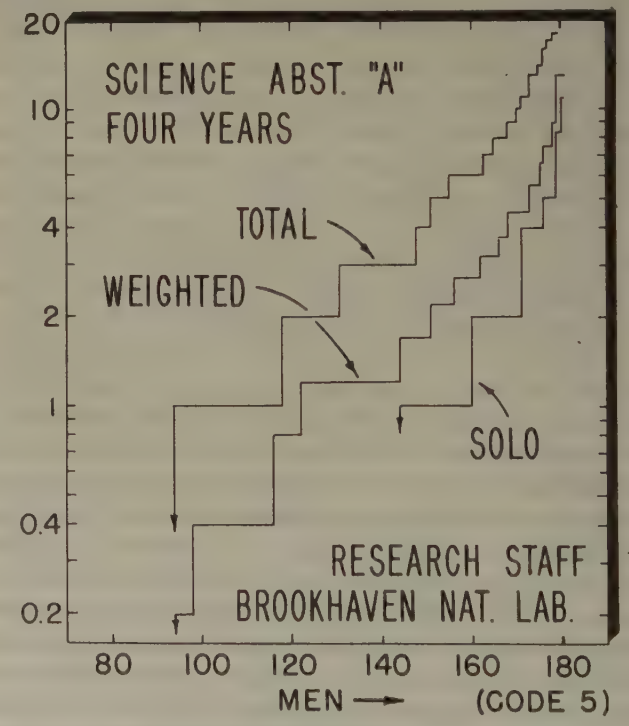


Fig. 5—Cumulative distributions on logarithmic scale for 3 cases at Brookhaven National Lab.

have published at nearly half the maximum rate for the "total" line. On the other hand, a large number of people who appear as co-authors in the "total" distribution have no "solo" publications whatever. This fact shows that the rapidly rising part of the line is due

largely to people who are capable of producing "solo" publications, a conclusion contrary to the expectation based on the "organizational hypothesis." In fact, the evidence is that publication of about half of the people is supported by the more productive ones who would be capable of publishing at relatively high rates strictly on their own.

The middle line marked "weighted" is obtained by dividing the credit for multiple-author publications equally among the various authors. For example, each man on a four-author publication receives a contribution of 0.25 publication. The "weighted" line again shows the steadily increasing trend and does not permit an undue credit to be given to people who, through organizational position, may appear as a joint author on a large number of publications. This furnishes further support for the thesis that the exponential trend of the cumulative distribution is a fundamental characteristic of the distribution of productivity among the members of the laboratory rather than some organizational artifact.

Another possible explanation which can also be discarded is that the distribution of degree of publication from one person to another is a consequence of the distribution in age of the population considered. In principle, some such distribution might be obtained as a result of distribution in age since people on the average have a maximum in their publication rate at an age of about 35. The distribution of publication in age has been studied by Lehman.[2] Some of Lehman's results for rate of publication as a function of age are shown in Fig. 6. Very similar results are obtained for other geographical samples. Actually, what Lehman has studied is not simply publication record but "creative production." He judges creative production by references found in histories of science and other similar sources. Since the distribution of workers in the laboratories considered in this study shows a fairly uniform distribution from age 25 to age 50, it is difficult to see how the variation in productivity with age as shown in Fig. 6 could result in a very small fraction of people with exceptionally high publication rates: from Fig. 6, we would estimate that the maximum publication rate would be perhaps twice the publication rate of the median man. In contrast to this, the studies shown for Figs. 2, 3, and 4 correspond to maximum publication rates substantially more than ten times that of the median man.

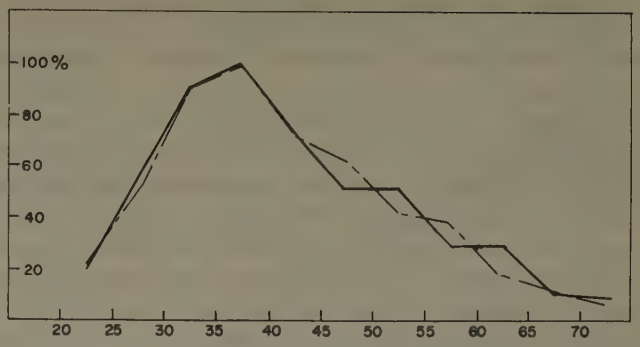


Fig. 6—Creative production rate in science and mathematics vs age for (solid line) nationals of 14 different countries other than Russia, England, France, Italy, Germany, and the U.S.A. and for (broken line) U.S.A.

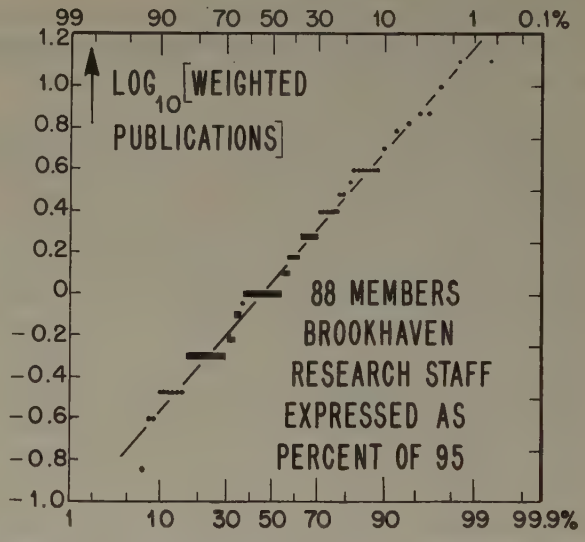


Fig. 7—Cumulative distribution of logarithm of "weighted" rate of publication at Brookhaven National Lab. plotted on probability paper.

IV. The Log-Normal Distribution of the Rate of Publication

The conclusion is thus reached that the exponential variation of productivity in the cumulative distribution graph is a characteristic feature of the statistics of productivity in a research laboratory. This conclusion receives further support from an additional analysis of the data which show that the logarithm of the rate of publication can be well represented as a normal distribution in the cases studied.

The validity of the assumption of a normal distribution can be tested by making use of so-called "probability paper." On such paper, the cumulative number of men is expressed on a percentage scale. This percentage scale is so distorted as to increase the spread on the scale at percentages near the extreme distribution. This results in stretching out the ends of the cumulative-distribution graph of Fig. 1(a) so that it becomes a straight line, provided the distribution itself is normal.

Such a test has been applied to the weighted rate of publication for the Brookhaven Laboratory shown in Fig. 5. The result is shown in Fig. 7. It is seen that a straight line can be drawn in a very satisfactory way through the data with the exception of the two extreme men. It should be noted that in many cases so many men were assigned the same publication number that they have been represented as solid blocks on the diagram rather than as individual points. This grouping together is a genuine effect in the case of people who

[2] H. G. Lehman, "Men's creative production rate at different ages and in different countries," *Sci. Monthly*, vol. 78, pp. 321–326; May, 1954.

published one "solo" publication during the period studied and thus have a logarithm of zero and those who have appeared on two publications or as a co-author of a single two-author publication and appear at logarithms of 0.3 and −0.3. Some of the other groupings have resulted artificially from the means of handling the statistics: for simplicity in listing the people, the scale of possible publications was divided into intervals and those whose publication rates fell in these intervals were grouped together. If this had not been done, the data would fall more closely along a straight line, *i.e.*, the "fit" to the normal distribution would be better.

Fig. 7 illustrates strikingly the range of variation in rate of publication—a factor of 40-fold between lowest 10 per cent and highest 5 per cent.

The fit shown on Fig. 7 is based on the assumption that the research staff of Brookhaven may be divided into two parts, one part containing 95 members who have some likelihood of publishing physics papers referenced in *Science Abstracts A* and 85 others with negligible likelihood of making such publications. The number 95 was found by trial and error to give the best straight line in Fig. 7. This arbitrary procedure does have justification in terms of the distribution of activities in the Brookhaven Research Staff. In fact if the list of members of the Research Staff at Brookhaven is examined name by name, it is found that many are biologists, medical physicists, and the like whose fields are not covered by *Science Abstracts*. The final conclusion is that all but 101 names are considered extremely unlikely to make publications abstracted in *Science Abstracts A*. Since the difference between 101 and 95 is negligible in respect to other uncertainties in the study, we may conclude that for the publishing part of the population the rate of publication is well represented by a normal distribution on the logarithmic scale, or for brevity, a *log-normal* distribution.

Generally similar fits are obtained for the Los Alamos data and for the National Bureau of Standards data. Furthermore, the data on "total" and "solo" entries in *Science Abstracts A* can be fairly well fitted by log-normal distributions. The fit is very "jumpy," however, since the only possible values for publication rates are integers. On the basis of the rather limited investigation that I have carried out to date in regard to the distributions for "solo" and "total" rates of publication, it appears that these also have log-normal distributions except that the rates of publication differ from the "weighted" rates by factors of 0.6 and 1.6, respectively.

It would be interesting to compare the statistics of science departments in universities with those of the large laboratories studied above. This has not yet been done except for the limited data on the Physics Department of Columbia University shown in Fig. 8. In spite of the smallness of the sample, the general trend of the data is such as to give confidence that the log-normal distribution will also hold in such cases.

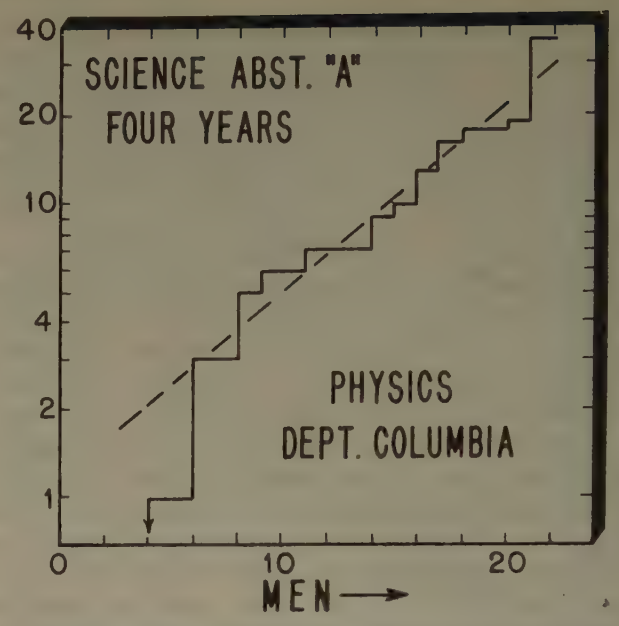


Fig. 8—Cumulative distribution on logarithmic scale for publications of the Physics Dept., Columbia Univ., for 4 years.

V. A Study of Patent Activity

Another measure of creative technical production, which is relatively readily available for study, is patent activity. Shown in Figs. 9 and 10 (opposite) are cumulative-distribution curves for patents for two large laboratories in the fields of electrical apparatus and communications. All of the data correspond essentially to "solo" publications since the number of joint patents is very small compared to individual patents.

It is instructive to compare patents with publications. Such a comparison is presented in Fig. 11 for a selected group of 60 men from one of the laboratories considered in Figs. 9 and 10. The most significant factor to note is that on the logarithmic scale, the patent distribution is markedly steeper.

VI. Speculations on the Origin of the Log-Normal Distribution

The very large spreads in productivity, for example the variation by nearly one hundred fold between extreme individuals in Fig. 7, are provocative of speculation. Most rates of human activity vary over much narrower limits, for example, pulse rates outside the two to one range from 50 to 100 per minute are extremely rare. Very few individuals walk at speeds outside the range of 2 to 5 miles per hour. In competitive activities involving trained and selected people, such as running the mile, the variation is much smaller, the ratio of speed for the mile between world's record and good high school performance being probably less than 1.5.

In the study presented here the individuals are presumably specially selected by natural ability and specially trained to accomplish scientific production. Yet the spread in rates is enormously greater than it is for the more physical activities discussed above. I believe

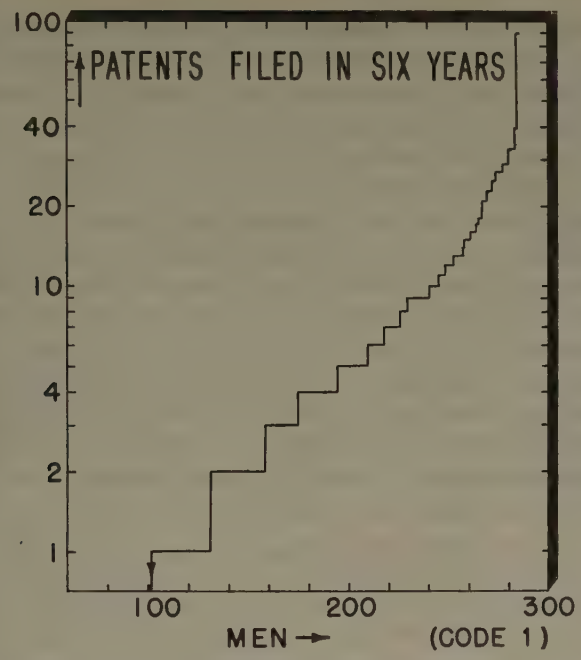


Fig. 9—Cumulative distribution on logarithmic scale for patents at a large industrial laboratory.

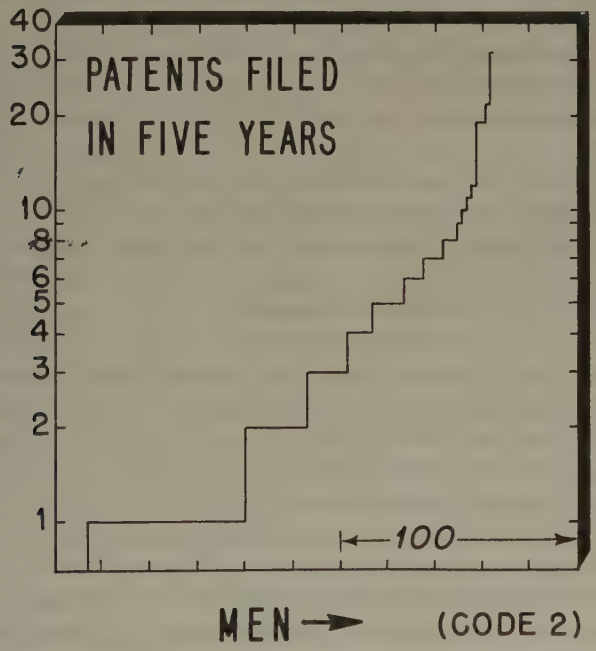


Fig. 10—Cumulative distribution on logarithmic scale for patents at another large industrial laboratory.

that it is possible to explain to some degree how such large variations in rate may occur in terms of certain characteristics of the creative scientific process. The basis of the explanation is that the large changes in rate of production may be explained in terms of much smaller changes in certain attributes. I shall illustrate this in terms of a simplified example of the inventing process.

In order to make an invention for which the United States Patent Office will issue a patent, it is, in general, necessary to conceive a new combination of features and

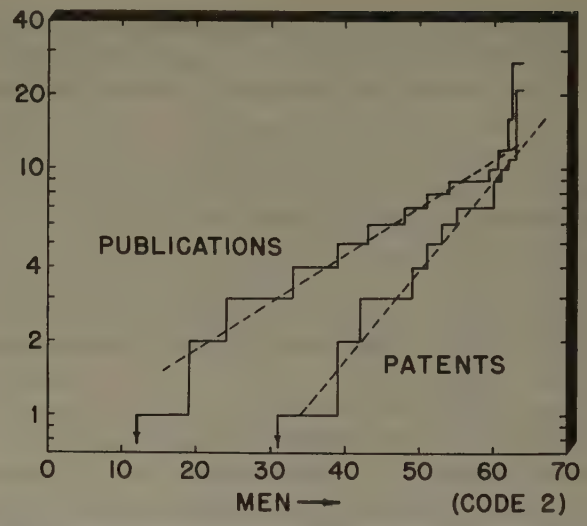


Fig. 11—Comparison of patent and publication activity for a group of research workers at a large industrial laboratory.

to appreciate how this combination may be useful. Let us suppose that the inventor perceives that he has made an invention when he appreciates the relationship between some number of ideas. For example, the automobile self-starter might have been conceived by recognizing the relationship of the following 4 ideas: the idea that a means of starting the engine without using human, muscular strength would be useful, the idea that the necessary energy could be held in reserve in a storage battery, the idea that a relatively small high speed electric motor could be used to turn the larger gasoline engine at starting speed, and the idea that the electric motor could be subsequently disengaged in order to avoid rotating it at excessive speeds.

Now let us suppose that there is some attribute of the human brain which allows an individual to be aware of "m" ideas and their relationships.[3] Then it follows that a man with $m=3$ will never invent the self-starter in the form discussed above whereas a man with $m=4$ can do so. A man with a higher value of m is much more likely to make the invention than a man with $m=4$. In fact, it may be established, by use of the formulas for permutations and combinations, that men with $m=5$, 6, and 7 can hold the 4 essential ideas in awareness (together with 1, 2, or 3 irrelevant ideas) in 5, 15, and 30 times as many ways as the man with $m=4$. This shows that a variation of 50 per cent in "brain capacity" ($m=4$ to $m=6$) can produce an increase in invention rate of 15-fold for inventions requiring the interaction of 4 ideas.

It may be instructive to illustrate the considerations presented above by an example which can be shown in detail. Suppose out of realm of idea associated with some field of endeavor an invention can be made by

[3] N. Rashevsky, "Mathematical Biophysics," University of Chicago Press, Chicago, Ill., ch. 29; 1938, presents very similar reasoning. His results are expressed in the form of equations rather than by numerical examples and lead to somewhat more general conclusions than those presented here.

holding ideas "1" and "2" in mind and seeing the relationship between them. Then a man with $m=2$ can make the invention in two ways as represented below:

$$(1, 2) \text{ and } (2, 1).$$

But a man with $m=3$ can think of these two ideas and some irrelevant idea x in six ways:

$$(1, 2, x),\ (2, 1, x),\ (1, x, 2),\ (2, x, 1),\ (x, 1, 2),\ (x, 2, 1).$$

Thus for every case in which the $m=2$ man can think of the idea, there are 3 ways in which the $m=3$ man can do it. Thus the $m=3$ man has 3 times as many chances to make the invention.

Evidently this advantage increases rapidly with the increasing complexity of the problem. For a 10-idea invention an 11-idea man has an 11-fold advantage over a 10-idea man; that is a 10 per cent increase in "mental capacity" produces a 1100 per cent increase in output. It is my impression that this sensitivity to the interaction of many factors in mental creativity is the key to the large variations in output found in this study. According to this explanation, the log-normal distribution in productivity then results from a normal distribution, over a relatively small range (say $m=8$ to $m=12$ in the model considered), of some attribute which controls productivity in a very sensitive way.

Still another way of rationalizing the log-normal distribution may be based upon the hypothesis that the interacting mental factors are of several different kinds rather than several of one kind, as in the case of several ideas as discussed above. For example, consider the factors that may be involved in publishing a scientific paper. A partial listing, not in order of importance, might be: 1) ability to think of a good problem, 2) ability to work on it, 3) ability to recognize a worthwhile result, 4) ability to make a decision as to when to stop and write up the results, 5) ability to write adequately, 6) ability to profit constructively from criticism, 7) determination to submit the paper to a journal, 8) persistence in making changes (if necessary as a result of journal action). To some approximation, the probability that a worker will produce a paper in a given period of time will be the product of a set of factors F_1, F_2, etc. related to the personal attributes discussed above. The productivity of the individual would then be given by a formula such as

$$P = F_1F_2F_3F_4F_5F_6F_7F_8. \tag{1}$$

Now if one man exceeds another by 50 per cent in each one of the eight factors, his productivity will be larger by a factor of 25. On the basis of this reasoning we see that relatively small variation of specific attributes can again produce the large variation in productivity.

The factor explanation discussed above also has an appeal from the point of view of the log-normal distribution. According to the formula, the logarithm of the product is the sum of the logarithms of the several factors. If we suppose that these factors vary independently, then to a good approximation their sum will have a normal distribution, and so, consequently, will the logarithm of the productivity. It seems to me that this is at present the most attractive explanation for the log-normal distribution.

In closing this section mention should be made of an attempt to fit the data by assigning to each individual a single parameter describing his creative potential. This parameter was referred to as "mental temperature" when the original lecture was given. It was introduced in analogy with the quantity β or $1/kT$ which occurs in the equation for rates of chemical reaction or thermionic emission. According to this hypothesis an individual i is characterized by a value β_i. In a situation s his rate of production is determined by a rate constant P_s and a barrier U_s, so that his rate of production is

$$P(i, s) = P_s \exp(-U_s\beta_i). \tag{2}$$

The rate constant P_s probably depends on β_i but in a relatively insensitive way, so that to a first approximation this dependence can be neglected.

On the basis of this equation, the difference between the two curves of Fig. 11 is to be attributed to a U value 1.7 higher for patents than for publications.

There appears to be a tantalizing possibility of establishing scales for U and β by comparing publications and patents and one laboratory with another. One might, for example, assume that the distribution of β values is the same in two laboratories having the same pay scales and similar working conditions. Then if U is chosen as unity for one activity in one of these, the scale of U can be chosen for the other cases in terms of the ratio of slopes like those of Fig. 11. Approximate values of P_s can be chosen by assuming that $\beta=0$ represents a situation in which the worker never lacks an idea to publish or an invention to patent so that his rate of production is limited by the mechanics of the situation. Such cases might correspond approximately to the most outstanding publishers in Dennis' study. On this basis P_s values of the order of 10 per year for either publications or patents might be chosen. I have made some attempts to establish scales of this sort but they are not well enough developed to warrant inclusion here.

VII. The Relationship Between Salary and Productivity

From the point of view of the economics of running a research laboratory, it is important to know the relationship between salary and productivity. For example, if the better paid men are more productive than their fellows in greater proportion than the increase in pay, then they are a sound investment. On the other hand, if they are less productive per salary dollar, then it may be wiser to hire relatively fewer of these outstanding people.

The question just posed is to some degree academic—anyone who has had to do with managing research knows that progress depends largely on a relatively

small number of exceptionally able individuals. He also knows that these people are usually substantially better paid than their fellows. How much better one can afford to pay outstanding people and still find them profitable is a quantitative question faced by many organizations during periods of rapid build up. The findings in this section throw some light on this question, the conclusion being that, in general, scientific productivity is so much greater for the outstanding people that in the current scientific labor market, it is unlikely that they will be overpaid.

It is clear, of course, that increasing salary of an individual will usually not increase his productivity much, if at all. In some cases it may even have the opposite effect by reducing incentive. What is studied here is the statistical relationship between salary and productivity as established by existing pay roll procedures. If any causal relationship is important in this connection, it is that high productivity of an individual causes the management to give him high rewards.

Before considering the method of investigating the statistical relationship between salary and productivity, it may be worth-while to say something about salary in general. In determining the salary of an individual in a research laboratory, the management takes into account many factors. Only one of these factors is considered in the previous parts of this study, namely, the rate of scientific production as measured by total numbers of publications or patents. This factor is probably rarely considered in a quantitative way. Instead, the usual procedure is for a group of people charged with supervising research workers to gather together and discuss the relative merit of the individuals. In such considerations, quantitative measures of the individual's contributions are seldom referred to. There probably does not exist at the present time any valid analysis of the various factors that are considered and their relative importance. Among them may be mentioned, however, the originality and importance of publications which are made. Thus quality as well as quantity is brought into account. Other factors which are certainly considered are the ability of an individual to carry out the techniques of his work, whether these be of a theoretical nature involving pencil and paper or the manipulation of apparatus; the ability to contribute to the solutions of problems of other workers in the organization; the ability to produce cooperation among other workers; the ability to attract productive candidates to the organization; the ability to influence the activities of other workers along lines which are more wisely chosen than they would choose themselves with respect to the goals of the organization as a whole; the ability to carry out activities which enhance the prestige of the organization. These and many other factors are generally considered in determining a man's "merit" and thus deciding what salary he should receive.

The assumption of this article is that merit and salary are somehow determined by the combination of such factors as those which we have discussed above. These factors are not closely correlated with each other, although it is probable that there is a tendency for outstanding ability in any one to be coupled with a probability of higher abilities in the others as well. The only attribute which has been studied here is simple quantitative productivity in the sense of publications and patents. If it is found that this attribute, which was studied purely for purposes of convenience, is strongly correlated with increasing salary, then it seems likely that the other attributes are also strongly correlated with salary.

It is not appropriate to consider simply the relationship of salary to productivity. The reason for this is that there is a general tendency of salary to increase with age, this being a recognition of increasing general judgment and experience with age as well as a socially acceptable procedure. Thus, in order to get a truly representative comparison of merit with productivity, it is necessary to correct for age. This procedure can be done in various ways; the one selected for this article being that associated with the concept of "merit quartiles."

The division of the population of a laboratory into "merit quartiles" may be illustrated with the aid of Fig. 12. This figure represents the salaries of a group of

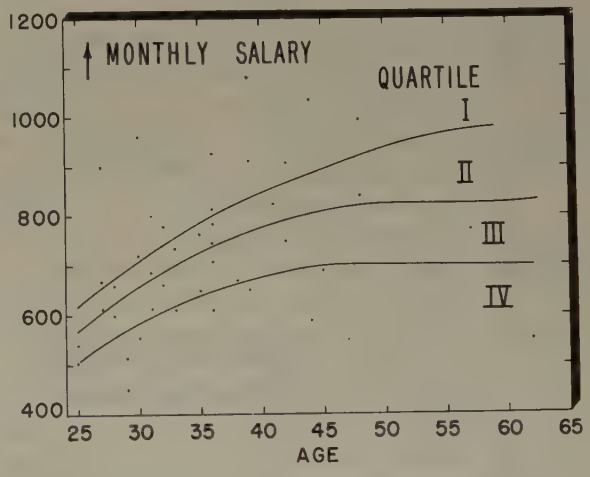


Fig. 12—Salary vs age (for a representative sample only of individuals) in a laboratory considered in this study with lines dividing the distribution into "merit quartiles"). Effective about October, 1954.)

individuals in a laboratory covered in this study. Each individual is represented by a point on the figure which shows his salary and his age. Three lines have been drawn on the figure dividing it into four groups of individuals, called quartiles. The procedure for drawing these lines is as follows: in each relatively small age interval the population of the laboratory is divided into halves such that half of the group gets more than the median salary and half less. Then the upper and lower halves are similarly divided into 2 equal parts so that each age interval is divided into 4 quartiles. This procedure is carried out for the various age intervals and then a smooth curve is drawn. These smooth

curves are drawn in such a way that at each age interval, approximately $\frac{1}{2}$ of the population of the laboratory lies in quartile I and approximately $\frac{1}{4}$ in each of II, III, and IV. Thus the people in the first or top quartile have approximately the same age distribution as those in the second, etc. Furthermore, all of the people in the top quartile obtain higher salaries than those in the second quartile at the same age.

These merit quartiles furnish a basis for dividing the laboratory into parts in accordance with salary but chosen in such a way that the age distribution in each part is similar. Thus any effect of varying productivity with age affects all the quartiles about the same way.

Fig. 13 shows a similar plot for the individuals in a U. S. government laboratory operated under Civil Service. It is to be noted that the highest salaries at any age range are substantially lower than those in the other non-Civil Service laboratory. The difference would be even more striking if the higher paid executive types of an industrial laboratory could also be shown.

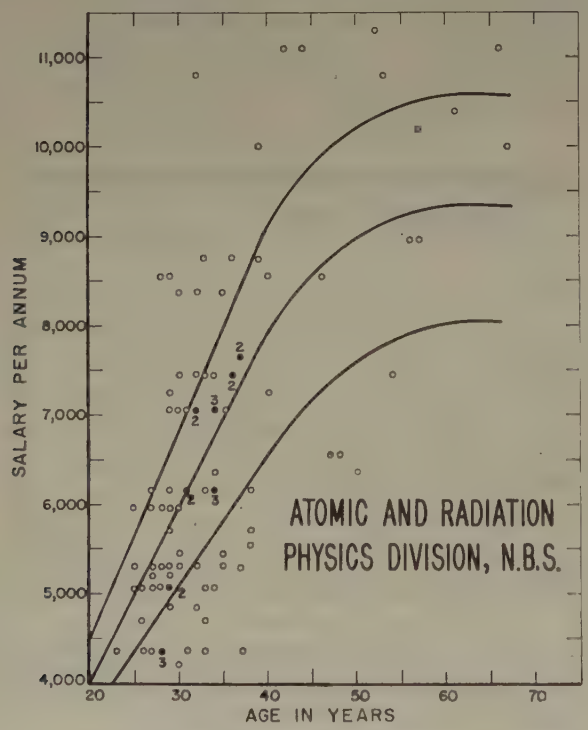


Fig. 13—Salary vs age for Atomic and Radiation Physics Div., National Bureau of Standards, together with "merit quartiles" divisions. (Effective about October, 1954.)

The use of merit quartiles, deciles, or similar divisions is playing a progressively more important role in salary administration.[4] One of the great advantages of the merit scale is that it provides an intuitively satisfactory way of ranking the individuals in an organization. The same would not be true if the men were ranked simply according to salary; thus a very able young man at a relatively low salary would be obviously out of place in company with an older group of average ability (but with more experience) at the same salary and it would be difficult to get any sense of order from such listing. On the other hand, a group of supervisors can come to agreement and reach decisions surprisingly easily about merit rank between people whose ages and salaries may differ by large amounts. I do not believe that it is evident in any *a priori* sense that such agreement would be expected; it appears rather an interesting and useful experimental result. In a sense, it is a surprising result since, as discussed above in this section, such diverse factors are considered in making the judgment. The agreement as to merit ranking by a supervisory group does not, of course, imply that the worth of the individual is truly assessed in any absolute sense. However, the large degree of consistency does imply that a useful and impartial tool for salary administration exists.

In principle, an organization can establish a family of merit curves at each raise period (allowing for cost of living adjustments, changing competition, etc.). The new salary for a man whose merit rank is correctly appraised can then be simply read off his location on the new curves. It somestimes happens, due perhaps to accidents of recruiting or due to changing skills on the part of the worker, that a revision of merit rating occurs. It is generally felt that only a fraction, say 50 per cent, of the correction should be made in any one raise since this will tend to smooth out fluctuations in the salary system.

A set of quartiles like those shown in the two previous figures have been prepared for the research staff of the Brookhaven National Laboratory. For each one of these quartiles, which contain about 46 men each, the publication records have been compiled as cumulative-distributions. These are not presented as graphs with steps since there are so many cases of overlap that the lines for different quartiles are very hard to separate. Consequently, smoothed distribution curves have been drawn through the steps in the manner illustrated in Fig. 1(a). The resulting curves are shown as Fig. 14.

From Fig. 14 it is readily seen that approximately the same numbers of people in quartiles I and II published, but that the amount of publication of the high publishing members of quartile I was larger by almost a factor of 2 than for the corresponding people of quartile II. Quartile III contains some individuals having high rates of publication and a smaller fraction of people publishing. The total amount of publication in quartile IV was substantially less than quartile III.

Similar diagrams have been made for other laboratories but there is no great uniformity in their characteristics. However, there is a very general trend which holds for all cases considered. This trend is for the average rate of publication per individual to increase steadily from quartile to quartile, being highest for the first or best paid quartile.

From the type of spread which is observed in Fig. 14,

[4] Employee interest is also high. For example, merit curves have been deduced from polls of employees of Bell Tel. Labs. by the Conf. of Prof. Tech. Personnel Inc., P.O. Box 625, Summit, N. J.

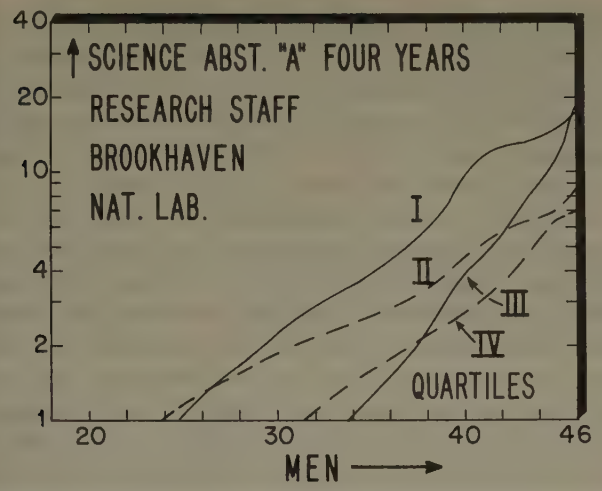


Fig. 14—Cumulative distributions (shown as smooth lines) for the four "merit quartiles" of the research staff of Brookhaven National Lab.

it is evident that publication per se is not given heavy weight in determining merit in terms of salary at Brookhaven. It is evident that something like 10 or 15 per cent of the individuals in quartiles III and IV exceed the publication records of about 50 per cent of the people in quartiles I and II. However, this is not sufficient to give them in terms of salary a recognition equal to those of quartiles I and II. Thus it follows that other factors certainly are being considered in determining salary.

From the general shape of the curves shown in Fig. 14, a very crude sort of an estimate can be made of the number of additional factors which must be taken into account in determining salary provided these factors are assumed to have importance approximately equal to amount of publication. For example, if we compare quartiles I and II we see that only 10 per cent, approximately, in quartile I exceed the maximum production of people in quartile II. This suggests that there might be something of the order of 10 other factors involved in weighting the people of quartile I, each one of these 10 other factors contributing to a group of about 10 per cent who exceed the performance of individuals in quartile II. Evidently this type of reasoning does not apply in the same way to quartiles I and III, but the fact that something between $\frac{1}{10}$ and $\frac{1}{4}$ of quartiles III and IV exceed most of the people in quartile I in terms of amount of publication suggests an analysis might lead to the conclusion that in determining subjectively the merit rating of an individual, salary reviewers act as if there were something like 4 to 10 factors of comparable importance to amount of publication.

I shall now return to the question taken up in the beginning of this section, namely, the quantitative relationship between salary and productivity. For the various laboratories considered in the study, sets of quartiles have been drawn and the average amount of production determined for each quartile. This information is gathered together in Fig. 15. The data have been expressed in terms of rate of activity in publication or patents per man-year. For the publications the total number of publications was used (not "solo" or "weighted"). It is observed that in all cases there is a monotonic increase in rate of activity with quartiles, increasing towards the highest paid quartile, quartile I. The actual spread in amount varies by a factor of about 9 for the most rapidly varying case and by a factor of a little over 3 for the most slowly varying case.

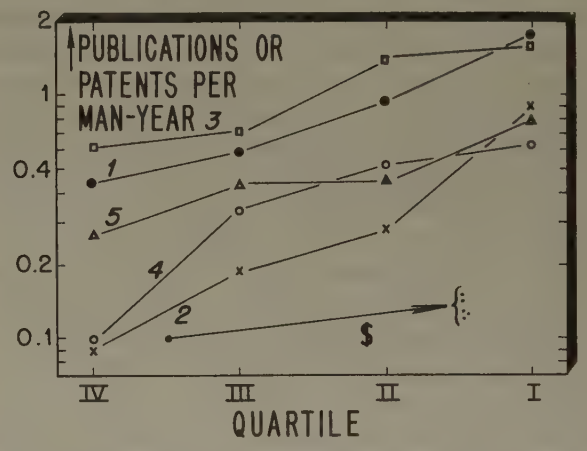


Fig. 15—Relationship between productivity and quartile number and salary and quartile number for several laboratories.

A comparison with salary is also indicated in the figure. The ratio of salary at the dividing line between quartiles III and IV to that between quartiles I and II at age 35 is also shown on the figure. Five cases have been considered and there are somewhat different spreads in salary for these. The line represents a sort of weighted average of the change in salary.

It is clear from inspection of the figure that in progression from quartile to quartile there is much less increase in salary than in productivity, in fact productivity lines rise 3 to 5 times as steeply as the salary lines. In other words, statistically an increase of 30 to 50 per cent in productivity is necessary for an individual to obtain an increase in salary of 10 per cent. However, as the reasoning given in connection with Fig. 14 shows, increase in scientific productivity alone is not sufficient to produce the increase in merit rating. In fact, coupled with the 30 to 50 per cent increase in productivity, there probably must be comparable increases in other kinds of contribution. In other words, the individual probably must become 30 to 50 per cent better in all respects in order to receive a recognition corresponding to a 10 per cent increase in salary.

VIII. Relevance to Civil Service Salary Scales

I should like next to discuss the relevance of these findings to the problem of Civil Service scientists in government laboratories. In addition to relatively low salaries positions in government laboratories are less attractive than those in industry or in universities. This is especially true in laboratories in the military estab-

lishments where periodically changing direction by officers who are not experienced in directing research frequently leads to morale problems. These problems have been thoroughly explored and reported in detail in the recent report[5] of the Riehlman committee of Congress. Clearly it is important to retain in these laboratories some highly-qualified, strong-minded, inspired leadership in order to prevent research effort from becoming thoroughly second grade.

This brings us to the most important conclusion in the study, and one which might possibly furnish a basis for action. The top salaries in government laboratories are substantially lower than both those in industry and in universities, at least for people in the latter whose line of work involves undertaking summer assignments and doing consulting. Even if there were no disadvantages aside from salary, the limits of salary set by Civil Service scales probably have a most severe effect on the leadership and originality available in government laboratories. Although these attributes have not been studied quantitatively, all of the findings in this article are consistent with the idea that leadership and originality increase very rapidly with salary just as do rate of publication and rate of invention. Cutting off the top of the salary scale at, say, $12,000 per year as compared to $18,000, will mean a reduction of productivity of 3 to 8 fold, according to the statistics deduced in connection with Fig. 15. Statistically, for the higher salaried man the return per dollar of salary is two to five times as great so far as individual productivity is concerned. If leadership qualities vary in a way similar to productivity, the return from increased salary will be enormously greater since an effective leader may substantially improve the output of many men.

In closing, I should emphasize that there are outstanding exceptions to most statistical results. Government laboratories do succeed in retaining a few outstanding individuals. These are unfortunately exceptions rather than the rule. Because of the present top limits on Civil Service salaries for scientists, the taxpayer's dollar is buying less research value than it should. A policy of having more highly paid positions might well double the return per dollar. It might also contribute significantly to offsetting the lead which the U.S.S.R. has currently gained in numbers of technical degrees granted in universities per year.

[5] Organization and Administration of the Military Res. and Dev. Programs, Twenty-fourth Intermediate Rep. of the Committee on Government Operations; August 4, 1954.

IX. Acknowledgment

The preparation of this paper has been made possible by the cooperation of a number of individuals and organizations. In particular, I would like to thank Dr. Lauriston S. Taylor and Mrs. Shea Kruegel of the National Bureau of Standards, Dr. L. J. Haworth of Brookhaven National Laboratory, Dr. John K. Herzog of Los Alamos Scientific Laboratory, and Dr. C. H. Townes of Columbia University. I would like also to acknowledge certain anonymous help. The appearance of this article in the Proceedings of the IRE results from a suggestion by E. W. Herold.

Correction

J. R. Wait and H. H. Howe, authors of "The Waveguide Mode Theory of VLF Ionospheric Propagation," which appeared on page 95 of the January, 1957, issue of Proceedings of the IRE, have brought the following corrections to the attention of the editors.

In (2), $(h/\lambda)^{1/2}$ should be replaced by (h/λ) and $S_n^{3/2}$ should be replaced by $\epsilon_n S_n^{3/2}$ where $\epsilon_0 = 1$, $\epsilon_n = 2 (n \neq 0)$.

In (3), (λ/n) should be replaced by (λ/h).

In Fig. 1, the abscissa labeled h should be L.

Molecular Amplification and Generation of Microwaves*

JAMES P. WITTKE†

The following paper is one of a planned series of invited papers, in which men of recognized standing will review recent developments in, and the present status of, various fields in which noteworthy progress has been made.—*The Editor*

Summary—**This paper is a general introduction to the field of amplification and generation of microwaves using molecular rather than electronic processes. The basic physical properties of molecular systems as related to amplification are reviewed. The properties of molecular amplifiers, such as gain, bandwidth, saturation power, and noise figure are discussed, and several specific types of amplifiers are described. These include the molecular-beam Maser, the "hot-grid cell," amplifiers excited by rf pulses and by "adiabatic fast passage," and amplifiers based on multilevel molecular internal energy systems, including "optically pumped" amplifiers.**

Molecular amplifiers may add very little noise to the signal to be amplified: noise figures under one db can be obtained. With suitable feedback, such amplifiers become oscillators of extremely high spectral purity. High gains can be achieved using regeneration, but bandwidths are relatively small. These range from the order of tens of kilocycles for amplifiers using a gaseous molecular system, to megacycles, using solids. Molecular amplifiers saturate at low input powers, of the order of microwatts. Variations of the devices discussed may provide a means of generating millimeter and submillimeter waves.

I. Introduction

IN FAMILIAR microwave devices, such as klystrons, magnetrons, and traveling-wave tubes, dc power is converted to microwave power by the interaction of moving charged particles (electrons) with a microwave field. Microwave fields can also interact with *uncharged* matter (molecules). In such "molecular interaction," there is no flow of charge, with its kinetic or positional energy being transformed to rf energy, but instead the *internal* energy of molecules is *directly* converted to microwave energy. This is a familiar process at very short wavelengths, for example, emission of visible light from a gas discharge. This light represents the direct transformation of internal electronic excitation energy of *neutral* atoms to electromagnetic radiation energy. However, there is a difference of profound importance between such optical radiation and the microwave radiation of interest in this paper. Atoms excited in a discharge tube have a very strong tendency to radiate light spontaneously. The presence of similar radiating atoms nearby has negligible effect on the emission, and the atoms emit independently of each other in an *incoherent* fashion. In the microwave frequency region such spontaneous emission of internal energy as radiation is relatively unimportant. Molecules must be *induced* to give up their internal energy by locating them in a microwave field that either is generated by neighboring radiating molecules or is externally applied; this induced emission is *coherent*, that is, phase-related to the general radiation field.

The motions of electrons in atoms and molecules are such that the associated energies form a discrete set, that is, only those motions leading to certain *allowed* internal energies can exist. Thus, the internal energy associated with the motion of electrons bound in molecules is quantized; an electron can only exist in certain *energy states*. It has become conventional to indicate the scheme of energy states for a molecule by a diagram such as Fig. 1. From this representation the term *energy level* has arisen, and is used interchangeably with *energy state*.

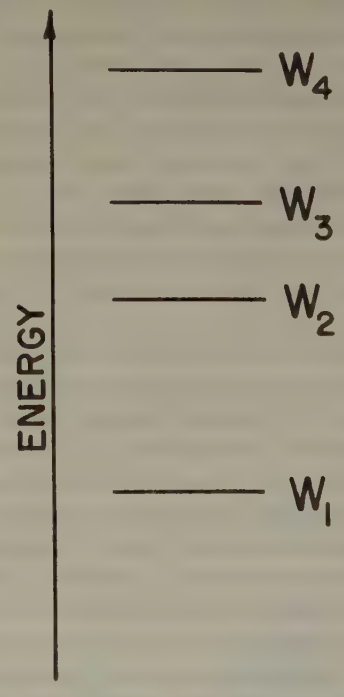


Fig. 1—Schematic representation of energy states (or levels).

The vibrational energies of atoms bound together in molecules and molecular rotational energies are similarly quantized and may also be represented by an energy level diagram. Other sources of internal energy, such as the orientation of molecular (and nuclear) dipole mo-

* Original manuscript received by the IRE, December 3, 1956.
† Radio Corp. of America Labs., Princeton, N. J.

ments in an applied electric or magnetic field, are also quantized.

The various internal energy states corresponding to different excitations of electronic motion generally lie a few electron-volts apart. Molecular vibrational energies are much smaller, typically of the order of 10^{-3} electron-volts; rotational energies are even lower, in the 10^{-4} to 10^{-5} electron-volt range, as are orientational energies of paramagnetic ions in usual laboratory magnetic fields (a few thousand Gauss). Nuclear moments are about three orders of magnitude weaker yet, corresponding to energies of only about 10^{-7} electron-volts.

Molecules in certain of their energy states can interact with a microwave radiation field of appropriate frequency and either absorb energy from the radiation field while jumping to a state of greater internal energy, or, under the influence of the radiation field, can give up some of their internal energy and drop to a state of lower energy. The amount of internal energy thus transferred, *i.e.*, the difference in energy of the two energy levels, $W_1 - W_2$, is linearly related to the frequency of the radiation field:

$$W_1 - W_2 = h\nu.$$

Here h is Planck's constant and ν is the frequency. vhf fields (at about 100 mc) correspond to energy differences of only about 4×10^{-7} electron-volts. These can therefore produce nuclear magnetic resonance; that is, they can interact with molecules to change the orientation of nuclear magnetic moments in fields of a few thousand Gauss. Microwave frequencies of about 10 kmc correspond to energies of about 4×10^{-5} electron-volts, which are typical of rotational and electronic paramagnetic energies. Visible light, as mentioned earlier, corresponds to the relatively large energy associated with changes of electronic motional energies (a few electron-volts). Because of the very small energy transfers associated with low frequencies, useful molecular amplifiers are more likely to operate at frequencies above 1000 mc.

Consider two energy levels of a molecule whose energy difference corresponds to a microwave frequency. If a molecule in the lower energy state is placed in a microwave field of this frequency, it will absorb energy and hop to the upper state. An atom in the upper state, on the other hand, will give up energy to the microwave field and drop to the lower level. The probability for both transitions is the same. Therefore, whether a system of many molecules exhibits a *net* absorption or emission of energy depends on whether more molecules are in the lower or upper energy state. All molecular systems when allowed to come to thermal equilibrium have more molecules in the lower of each pair of states, and hence are absorptive. However, it is possible to build devices that will disturb the molecular system and put it in an emissive condition where more molecules are in the upper of a pair of states. Such a disturbed, emissive system is a "molecular amplifier": a microwave field incident on it will take up energy from the molecules. By providing suitable feedback, a "molecular oscillator" can be made.

Several methods of producing an emissive condition have been devised. One that has been tested is the molecular-beam Maser,[1,2] in which a beam of ammonia molecules is physically separated into two beams, one consisting of upper-state molecules and the other of lower-state molecules. The upper-state beam is then used in a resonant cavity as the emissive molecular system of a microwave amplifier. As an oscillator the beam Maser has exceedingly high spectral purity; as an amplifier it has only a very narrow amplification bandwidth.

Another device, the "hot-grid cell," also uses ammonia gas. However, unlike the beam Maser, this is a "sealed off" gas system that does not require continuous pumping. An emissive state is maintained by selective reflection of upper-state molecules at one wall. In addition to the advantage of eliminating pumps, the amplification bandwidth is an order of magnitude larger than in the beam-type Maser. It is still only tens of kilocycles, however.

To get greater bandwidths without loss of gain, molecular systems of higher density are needed. It is expected that megacycle bandwidths can be attained using solids. Two methods of exciting such systems by interchanging the populations of two levels have been found. These are: 1) excitation by applying a short controlled pulse of microwave power at the transition frequency, and 2) excitation by "adiabatic fast passage," where a strong exciting microwave field is swept in frequency past the transition frequency. However, these excitation methods are essentially pulsed ones, giving only intermittent amplification. Another method of exciting a solid molecular system that operates continuously has been developed. In this, a strong microwave field equalizes the populations of two energy states and amplification is secured at a lower frequency by inducing transitions between one of these two levels and an intermediate undisturbed level. Whereas conventional tubes require dc power to operate, all of these methods of exciting solid systems entail the supplying of energy to the system at microwave frequencies. In a solid, the lifetime of an excited state during which it can interact with radiation is determined in part by thermal motions of the lattice atoms. Therefore, solid-state devices seem to work best at very low (liquid helium) temperatures; this practical disadvantage will probably be overcome by future developments of materials in which interactions with the lattice are very weak.

[1] J. P. Gordon, H. J. Zeiger, and C. H. Townes, "The Maser—new type of microwave amplifier, frequency standard, and spectrometer," *Phys. Rev.*, vol. 99, pp. 1264–1274; August 15, 1955.

[2] The term "Maser," an acronym for "microwave amplification by stimulated emission of radiation," has been coined to describe the general class of microwave amplifiers based on molecular interaction. It is often used in a more restricted sense to refer to one form of molecular amplifier, that using a beam of excited molecules.

A very narrow band gaseous amplifier that is excited, not with microwave energy but with visible light, is also being worked on. This should provide, as does the molecular beam Maser, a tuned element of exceedingly high Q for an "atomic clock" or frequency standard.

There are two basic features of molecular amplification and generation that make it attractive in comparison to electronic devices. First, molecular amplification does not have many of the sources of noise that plague electronic amplification, such as flicker noise, induced grid noise, shot noise, and partition noise.[3,4] Molecular amplifiers can therefore have low noise figures and molecular oscillators can have high spectral purity. Second, the frequencies are determined by the internal molecular structure. Therefore, the limitations on the generation of very short microwaves imposed by electron transit time effects of conventional tubes no longer restrict the attainable frequencies. Of the disadvantages of molecular amplifiers, the narrow amplification bandwidth is perhaps the most serious.

The next section gives a general discussion of the basic physical processes involved in emissive molecular systems and of the requisite molecular properties. Those who are familiar with the basic concepts in the interaction of microwaves with matter will wish to skip over this section. The specific requirements for amplification and oscillation are discussed in Section III; Section IV discusses in detail the practical approaches to the subject outlined earlier. A discussion of the present state of the art and comments on possible future developments in Section V conclude the paper.

II. Basic Physical Properties and Processes of Molecular Systems

A. Description of a Single Molecule

Numerous experiments have shown that an isolated molecule cannot have arbitrary internal energy, but can only have one of a *discrete* number of energies; that is, molecular internal energies are *quantized*. This behavior is in contrast to that of a free electron, whose kinetic energy, or potential energy in an electric field, can assume any of a continuous range of values.[5] Molecules and electrons may therefore be expected to have basically different types of interaction with electromagnetic radiation. To study molecular interactions, the properties of molecules in the various internal energy states must be known.

According to quantum theory, the state of a molecule is completely specified by a *state function*. Any general state of a molecule can be expressed by a linear combination of the state functions that describe the individual quantized energy states. Denote the function corresponding to the state with internal energy W_i by ψ_i; then any general state ψ can be expressed by:

$$\psi = \sum_i a_i \psi_i. \tag{1}$$

The a_i's, which may be complex, are analogous to Fourier coefficients in a Fourier decomposition, and are called "probability amplitudes." They have the physical significance that if the internal energy is measured, the probability that the value W_i will be obtained is equal to $|a_i|^2$. Eq. (1) has the interpretation that unless $a_i=0$ for $i\neq j$ and $|a_j|=1$, the energy of the system is *uncertain:* an energy measurement may yield *any* of the values W_i for which $a_i\neq 0$. A state describable by such a state function is called a *superposition* energy state, as it is made up of a linear combination of pure energy states ψ_i. In predicting the result of an energy measurement, it is seen that only the *magnitude* of the a_i's is important. Other properties of the system in a superposition state, however, such as its interaction with microwaves, depend on the relative *phases* of the various a_i's, as well as on their magnitudes. There are certain processes that do not change the energy of the molecule, but produce changes in these relative phases; the interaction process between molecules and radiation is critically dependent on such processes.

B. Description of Many-Molecule Systems

Thus far, only isolated single molecules have been considered. When a number of such molecules are assembled, the interaction between these elements may be weak, or sporadic. In either case, the system of individual-molecule energy levels may still be used, with the aid of statistical methods, to predict the behavior of the many-molecule macrosystem. On the other hand, in cases where the interactions are continuous and strong, the individual-molecule energy level scheme breaks down and must be replaced by one treating the macrosystem as a whole. Systems with weak or intermittent interactions between the elements will be of interest in this paper. Even in a solid, molecular systems that are but weakly coupled to each other and their surroundings may be found. Certain paramagnetic ions, introduced as impurities in a host crystal lattice, are examples.

Consider a system of many molecules. If the internal energy of one of the molecules is measured, it will be found to be one of the discrete allowed values. The question arises: what can be said about the distribution of the molecules among these allowed energy states? The answer given by statistics is the following. If the system is in thermal equilibrium at an (absolute) temperature T, in any sample containing many molecules the ratio of the number of molecules with energy W_1 to the number of molecules with energy W_2 is given by:

$$\frac{N(W_1)}{N(W_2)} = \frac{N_1}{N_2} = \exp\left[-\frac{(W_1 - W_2)}{kT}\right] \tag{2}$$

[3] J. R. Pierce, "Physical sources of noise," Proc. IRE, vol. 44, pp. 601–608; May, 1956.

[4] J. L. Lawson and G. E. Uhlenbeck, "Threshold Signals," McGraw-Hill Book Co., Inc., New York, N. Y.; 1950.

[5] The kinetic energy and any positional potential energy of a molecule are similarly unquantized. However, we are considering only "molecular interactions," where changes of internal, rather than kinetic (or positional), energy are involved.

where $k = 1.38 \times 10^{-16}$ erg/°K (1.38×10^{-23} joule/°K) is Boltzmann's constant. This Boltzmann distribution has the properties that states of lower energy are more highly populated than states of higher energy and that the population ratio of any two states can be enhanced by lowering the temperature and reduced by raising it.

C. Relaxation Effects

The Boltzmann distribution of molecules among the various possible energy states is an *equilibrium* one; that is, as long as the temperature of the system is held constant, once this distribution is attained, it will remain the same indefinitely.[6] Any distribution whatever, if it is left undisturbed for a sufficient length of time, will spontaneously change until it is an equilibrium one. The processes that produce such changes in an arbitrary distribution are known as the "relaxation mechanisms." Interaction with a "black-body" radiation field, collisions between molecules, and electric and magnetic dipolar interactions between molecules are among such processes of importance in molecular amplifiers.

For convenience in handling many problems, the relaxation processes are divided into two classes which are not necessarily mutually exclusive. These correspond to the two different ways a system can deviate from equilibrium. Once the total number of molecules in each energy state is known, the total internal energy W of the molecular system is given by

$$W = \sum_i N_i(W_i) \times W_i.$$

If the total energy of the molecular system differs from its thermal equilibrium value W_{eq}, spontaneous changes will occur that result in a net transfer of energy between the internal degrees of freedom of the molecular system and its surroundings (a heat reservoir). Those processes that contribute to this exchange of energy are called "longitudinal" relaxation processes. In many cases of practical importance, the displacement of the molecular internal energy W from its equilibrium value W_{eq} decreases exponentially with time:

$$\frac{d(W - W_{eq})}{dt} = -\frac{1}{T_1}(W - W_{eq}).$$

The reciprocal of the decay constant, which has the dimensions of a time, is known as the "longitudinal" (or "spin-lattice") relaxation time. It is conventionally designated T_1.[7]

[6] It thus must correspond to a state of maximum entropy, or maximum disorder.

[7] The reader is warned of the possible confusion of the absolute temperature, T, and the relaxation times T_1 (and T_2). This symbology has become standard in the field, and hence is retained here. It arose in the field of nuclear magnetic resonance, where the internal energy is the magnetic dipolar or "spin" orientation energy of nuclei in an applied magnetic field. The term "spin-lattice" relaxation also arose in nuclear magnetic resonance, where the crystal lattice constitutes the heat reservoir.

There is another kind of relaxation process. Since the equilibrium state is one of complete randomness or molecular chaos (maximum entropy), any coherence or definite phase relationship between the various molecules constituting the system corresponds to a (partially) ordered, and hence nonequilibrium, state. In this case, the energy of the system W need not depart from its equilibrium value W_{eq} to produce a nonequilibrium state. Relaxation processes that tend to destroy such order in the system are known as "transverse" processes, and where they can be adequately described by an exponential decay of the order are describable phenomenologically by a "transverse" (or "spin-spin") relaxation time T_2. Examples of this type of relaxation process can be found that either can simultaneously transfer energy between the system and surroundings, or can involve only members of the system itself, and hence cannot exchange energy with the heat reservoir. A collision between two gas molecules, where internal energy can be transformed to kinetic energy of the molecules is an example of the former; the magnetic dipolar interaction between two localized spins in a crystal is an example of the latter.

D. Molecular Interaction with a Radiation Field

A molecule can exchange energy with an oscillating electromagnetic field only if the frequency of the oscillation is related to the allowed internal energies of the molecule by the Bohr frequency condition

$$W_i - W_j = h\nu, \tag{3}$$

where W_i, W_j are the internal energies of the ith and jth quantum states, ν is the frequency of the radiation, and $h = 6.624 \times 10^{-27}$ erg-sec (6.624×10^{-34} joule-sec) is Planck's constant. The energy in a monochromatic electromagnetic wave is also quantized; that is, the energy in the wave comes in "packets," or *photons*, and can only change in finite steps corresponding to the energy of a photon. For a wave of frequency ν, the energy of the photons is just $h\nu$. The interaction may then be considered to be either one of two processes: the absorption of a photon by the molecule with a corresponding increase in internal energy, or the emission of a photon with a corresponding drop in internal energy. With this picture the above frequency condition (3) follows immediately from the principle of conservation of energy. The apparent discrepancy between a quantized radiation field of discrete photons and the continuously variable electric and magnetic fields usually dealt with can be resolved by considering the size of a photon. For a microwave frequency of 10 kmc, the photon energy is only 6.6×10^{-17} erg (6.6×10^{-24} joule); a wave at this frequency carrying a microwatt of power has a flux of 1.5×10^{17} photons/sec. It is because ordinary practice deals with such huge numbers of photons that the dis-

creteness of the wave energies does not generally make itself manifest.[8]

There are three basic types of radiation field-molecule interaction: absorption, induced or stimulated emission, and spontaneous emission. In absorption, as the name implies, a photon is absorbed by the molecule, which is then lifted to a state of higher energy. Induced emission is the reverse process, whereby, under the action of an applied electromagnetic field, a molecule emits a photon at the frequency of the applied field and drops to a lower internal energy level. In spontaneous emission, a molecule in an excited energy state, *i.e.*, an energy state other than the lowest, even though it is undisturbed by an applied field, emits a photon at the characteristic frequency given by the Bohr frequency condition and drops to a lower energy state. These types of interaction were treated on a phenomenological basis by Einstein[9] before an adequate microscopic quantum picture was available. His "B-coefficient" gives the probability for either absorption or induced emission; his "A-coefficient" gives the spontaneous emission probability. In amplification, we are clearly dealing with induced emission. In the case of a molecular microwave generator, the basic process is *coherent* spontaneous emission. This can alternatively be considered a case of *self-induced* stimulated emission, where the energy supplying the inducing field comes from the molecular system itself.

It is not possible to cause transitions between every two internal energy states by means of electromagnetic radiation. In addition to the conservation of energy requirement given by (3), momentum conservation and other requirements must be met. The effect of this is to impose restrictions on what pairs of states may be coupled by radiation. These restrictions are known as "selection rules," and are usually expressed in terms of allowed changes in the quantum numbers specifying the internal states. For example, the rotational energy of a simple diatomic molecule may be written as

$$W_J = BJ(J+1)$$

where B is a constant depending on the molecule and J is the rotational quantum number. The usual selection rule for transitions between the states of energy W_J is given by

$$\Delta J = J_{\text{final}} - J_{\text{initial}} = \pm 1,$$

i.e., the rotational quantum number must change by one unit when a photon is emitted or absorbed, the plus sign corresponding to absorption, and the minus to emission. This is because each photon carries one unit of angular momentum, which must be conserved.

A very important point about absorption and emission must be made. Both a microscopic quantum mechanical treatment and Einstein's phenomenological treatment give the result that, for a given applied microwave field strength, the probability of a molecule in the lower of two energy states absorbing a photon is exactly equal to the probability of a molecule in the upper of the same two states giving out a photon by induced emission. This has the consequence that any macrosystem that is in a state where two energy levels are equally populated will be completely transparent to radiation at the frequency corresponding to their energy difference. Neglecting the usually insignificant spontaneous emission effects, it is only an imbalance in populations that produces an observable effect. For computational purposes it is therefore possible, when considering transitions of molecules between two energy levels, to "pair off" the molecules as far as possible, and to deal only with the "excess" molecules in the more highly populated state.

To make this somewhat clearer, consider a gas in thermal equilibrium. Since radiation at only one frequency will be of interest, only the two states coupled by radiation at this frequency need be considered. Let the upper energy state be designated 2), the lower 1); let there be a total of N molecules in the two states.

$$N_1 + N_2 = N.$$

From (2),

$$\frac{N_2}{N_1} = \exp\left[-\frac{W_2 - W_1}{kT}\right] = \exp\left[-\frac{h\nu}{kT}\right]. \tag{4}$$

Solving these equations for N_1 and N_2 gives

$$N_1 = \frac{N}{1 + \exp\left(-\frac{h\nu}{kT}\right)},$$

$$N_2 = \frac{\exp\left(-\frac{h\nu}{kT}\right) N}{1 + \exp\left(-\frac{h\nu}{kT}\right)}.$$

"Pairing off" molecules, the "excess population" is

$$N_1 - N_2 = N \tanh\left(\frac{h\nu}{2kT}\right). \tag{5a}$$

At microwave frequencies, $h\nu/2kT \ll 1$ generally holds, and (5a) becomes

$$N_1 - N_2 \approx \frac{h\nu}{2kT} N. \tag{5b}$$

[8] The question of the meaning of *phase* when a radiation field is considered to consist of particle-like photons, and other questions dealing with the "wave-particle duality" of radiation are too involved to go into here. The interested reader is referred to texts on quantum theory for further discussion, *e.g.*, D. Bohm, "Quantum Theory," Prentice-Hall, Inc., New York, N. Y. chs. 1 and 2; 1951, or W. Heitler, "The Quantum Theory of Radiation," University Press, Oxford, Eng., 2nd ed.; 1950.

[9] A. Einstein, "On the quanta theory of radiation," *Phys. Zeit.*, vol. 18, pp. 121–128; March 15, 1917. For a brief review of Einstein's argument, see, E. U. Condon and G. H. Shortley, "The Theory of Atomc Spectra," Cambridge Univ. Press, Cambridge, Eng., ch. 4; 1951.

(At extremely low temperatures, the exact (5a) must be used.) If radiation at frequency ν is incident on the gas, it will absorb energy (since $N_1 > N_2$) at the same rate as a gas composed of $(h\nu/2kT)N$ molecules all of which are in the lower of the two energy states.

It has been seen that an electromagnetic field of the proper frequency can induce transitions between the energy levels. It must be remembered, however, that while this is going on, the relaxation mechanisms are operative, tending to restore the system to thermal equilibrium. For weak transition-inducing fields, the relaxation mechanisms are strong enough to maintain the system in an absorptive state not much different from that of thermal equilibrium. However, if the electromagnetic field strength is increased, molecules tend to undergo induced transitions to the upper energy state faster than the relaxation processes can restore them to the lower state. The effective "pairing off" of molecules is then shifted from that at equilibrium, and there are fewer molecules now in the "excess" to absorb. The total absorbed power does not decrease, as the power absorption per molecule is greater at higher fields. It does reach a limit, however, determined by the maximum rate that the relaxation processes can remove the internal energy from the molecular system thus supplied by the microwave field. Under these conditions, the microwave absorption is said to be "saturated." An analogous situation will be encountered in considering amplification.

The above discussion has assumed that the energy levels are perfectly sharp, that is, that only one (monochromatic) frequency couples two energy levels. This is not strictly true: transitions may be induced by a band of frequencies centered at the frequency given by (3). Thus, absorption or emission spectral "lines" have a finite frequency width which can be ascribed to a "width" of the corresponding energy levels. The physical reason for this width is that because of relaxation processes, a molecule interacts with the radiation field for only a finite time before it is "dephased" and (effectively) the interaction stops momentarily. But in an interaction time $\sim T_2$, a molecule will "see" essentially the same number of cycles of the microwave field as long as the frequency lies in a band of frequencies of width $\Delta\nu \approx (1/T_2)$. In other words, a molecule is not able to tell what frequency is acting on it to within a range $\Delta\nu$ in the time T_2 before the interaction is interrupted. The spectral width of a molecular resonance should thus be given by $\Delta\nu T_2 \sim 1$, with short relaxation times leading to broad lines and conversely. This is as observed: in a gas, where T_2 is inversely proportional to the pressure, the observed line width is also proportional to the pressure. Dephasing processes not describable by a relaxation time T_2, such as the Doppler effect, have a similar result. Such effects are commonly met with in the microwave spectroscopy of gases and provide a means of studying molecular interaction processes in detail.[10,11] In a solid, where the molecules are very near to each other, strong interactions, leading to short relaxation times, are frequently encountered. Resonances in solid systems are thus apt to cover a broad band of frequencies. (Resonances of over a hundred megacycles are generally too broad to use for amplification purposes, but widths roughly one megacycle and up can be found.)

In some cases it happens that certain frequencies couple more than one pair of states. This may happen because two or more internal states correspond to the same energy (degeneracy), or because two or more pairs of levels "accidentally" are separated by the same energy gap. The first of these cases is the more common. However, in many systems of interest neither effect occurs. To simplify the discussion, it will be assumed that neither occurs in all the following. It is a good approximation to ignore the effects of all energy states but the two that are directly coupled. This reduces the situation to a relatively simple two-state case.

E. Properties of a Two-State System

In the case that only two energy levels are of importance, one deals with a system of molecules that interacts with the radiation field only when the frequency of the field is near the resonant frequency ν_0. Such a radiation field induces transitions between the two energy states, molecules in the lower state undergoing transitions that absorb energy from the radiation field and lift them to the upper energy state, and molecules in the upper energy state giving up energy to the field and dropping to the lower state. As mentioned earlier, the transition probability for an atom in the lower state to absorb a photon and jump to the upper state is exactly equal to that for an atom in the upper state to emit a photon and jump to the lower state (neglecting the usually small spontaneous emission effects). A semiquantum mechanical calculation of these transition probabilities is given in the Appendix. The basic result of interest here is that if a molecule is in either one of the energy states at time $t=0$, at time t the probability that it has undergone a transition and is in the other state is given by:

$$\text{Transition Probability} = \frac{\left(\frac{pE}{h}\right)^2}{(\nu-\nu_0)^2+\left(\frac{pE}{h}\right)^2} \cdot \sin^2\left\{\pi\left[(\nu-\nu_0)^2+\left(\frac{pE}{h}\right)^2\right]^{1/2} t\right\}. \quad (6)$$

[10] W. Gordy, W. V. Smith, and R. F. Trambarulo, "Microwave Spectroscopy," John Wiley and Sons, Inc., New York, N. Y.; 1953.
[11] C. H. Townes and A. L. Schawlow, "Microwave Spectroscopy," McGraw-Hill Book Co., Inc., New York, N. Y.; 1955.

A dipole transition has been assumed, with p the molecular electric dipole moment and E the amplitude of the applied microwave field. (Although the electric case has been assumed, all expressions are equally valid if E is replaced by a microwave magnetic field H[12] if p is then taken as the *magnetic* dipole moment.) ν is the frequency of the applied field and $\nu_0=(W_2-W_1)/h$. Eq. (6) is plotted in Fig. 2; as shown there, the transition prob-

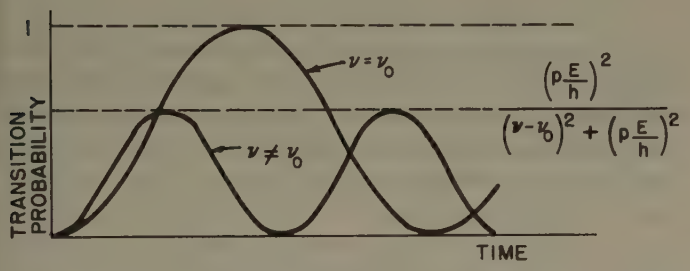


Fig. 2—Transition probabilities between energy states as a function of time for molecules initially in one of two microwave-coupled states when subjected to microwave radiation at or near the resonant frequency.

ability oscillates between zero and

$$\frac{\left(\frac{pE}{h}\right)^2}{(\nu-\nu_0)^2+\left(\frac{pE}{h}\right)^2}.$$

On resonance, $(\nu=\nu_0)$, a molecule oscillates between the two states, while somewhat off resonance, a molecule that starts in one state never quite gets to the other (with certainty) before the process is reversed.

The average power flow to or from the radiation field due to transitions depends on a suitable averaging of transition probabilities, the averaging being dependent on the physical situation envisioned. One important case is that of collisions randomly distributed in time determining the interaction period. From (6), the instantaneous rate of energy transfer is

$$P(t)=P(t-t_1)=h\nu_0\times\frac{d}{dt}(\text{Transition probability})$$

$$=\frac{\pi h\nu_0\left(\frac{pE}{h}\right)^2}{\left[(\nu-\nu_0)^2+\left(\frac{pE}{h}\right)^2\right]^{1/2}}\cdot\sin\left\{2\pi\left[(\nu-\nu_0)^2+\left(\frac{pE}{h}\right)^2\right]^{1/2}(t-t_1)\right\}. \quad (7)$$

Here the last interruptive collision occurred at time t_1.

[12] Strictly speaking, B should be used instead of H for the microwave field. Common usage in the field, however, replaces B with H; to avoid confusion with the literature, H will be used throughout this paper.

The probability that a molecule had its last collision between times t_1 and t_1+dt_1 is given by

$$\frac{1}{T_2}\exp\left[-\frac{(t-t_1)}{T_2}\right]dt_1.$$

The average power is found by averaging (7) over this distribution of times t_1:

$$P_{avg}=\int_{-\infty}^{t}P(t-t_1)\,\frac{1}{T_2}\exp\left[-\frac{(t-t_1)}{T_2}\right]dt_1$$

$$P_{avg}=\frac{h\nu}{2T_2}\left(\frac{pE}{h}\right)^2\frac{1}{(\nu-\nu_0)^2+\left(\frac{1}{2\pi T_2}\right)^2+\left(\frac{pE}{h}\right)^2}.$$

The above averaging over collision times implicitly assumes that $T_1=T_2$. A calculation made under the assumption of $T_1\neq T_2$ gives the more general result

$$P_{avg}=\frac{h\nu}{2T_2}\left(\frac{pE}{h}\right)^2\frac{1}{(\nu-\nu_0)^2+\left(\frac{1}{2\pi T_2}\right)^2+\frac{T_1}{T_2}\left(\frac{pE}{h}\right)^2}. \quad (8)$$

This is the often-observed Lorentz line shape (see Fig. 3). From the last factor in (8) it is seen that the power

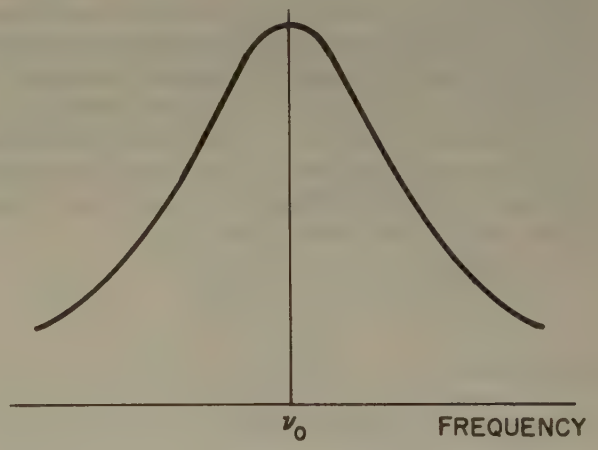


Fig. 3—Average power transferred between molecules and a microwave field at frequencies near resonance, showing the often-observed Lorentz shape.

is roughly independent of the frequency as long as

$$(\nu-\nu_0)^2\ll\left(\frac{1}{2\pi T_2}\right)^2+\frac{T_1}{T_2}\left(\frac{pE}{h}\right)^2,$$

while it drops off rapidly with increasing departure from resonance in the range

$$(\nu-\nu_0)^2\gg\left(\frac{1}{2\pi T_2}\right)^2+\frac{T_1}{T_2}\left(\frac{pE}{h}\right)^2.$$

The frequency bandwidth for interaction is thus approximately given by

$$(\nu - \nu_0)^2 \approx \left(\frac{1}{2\pi T_2}\right)^2 + \frac{T_1}{T_2}\left(\frac{pE}{h}\right)^2. \quad (9)$$

This illustrates a general feature common to all physical situations: for short transverse relaxation times T_2, the interaction is spread over a broad band of frequencies, and conversely, and for high microwave field strengths, the interaction frequency width is similarly (saturation) broadened.

With a different physical situation, such as in a device employing a beam of molecules where the interaction time is the time for the beam to traverse the device, the time averaging is different from the above and the resulting line shape is non-Lorentz. The basic ideas and general results are the same whatever the proper averaging, however.

F. Classical Treatment

The foregoing has been a semiquantum-mechanical *microscopic* approach, where the results of experiments with a large number of molecules were deduced on the basis of what happens to individual molecules. In most cases of interest for amplification, only the gross *macroscopic* behavior is important, and all results can be obtained on a phenomenological basis using a purely classical treatment.

The connection between the microscopic and a macroscopic treatment is easily seen in the case of a system of electron spins in a magnetic field, for example. The elementary dipoles can exist in only two energy states, corresponding to alignment roughly along and against the field. As seen from (5b), at thermal equilibrium the excess number of spins in the lower energy state, leading to alignment with the field, is given by

$$N_1 - N_2 = \frac{h\nu}{2kT} N.$$

Now, however,

$$h\nu = 2\mu H,$$

where μ is the magnitude of the component of an elementary dipole along the field, so that

$$N_1 - N_2 = \frac{N\mu}{kT} H.$$

The macroscopic magnetic moment is given by

$$M = \mu(N_1 - N_2) = \frac{N\mu^2}{kT} H.$$

From this, a static magnetic susceptibility χ_0 can be defined by

$$M = \chi_0 H,$$

with

$$\chi_0 = \frac{N\mu^2}{kT}.$$

(The discrepancy by a factor of 3 between this and the classical Langevin formula is apparent rather than real: μ is the field-parallel component of the total dipole moment μ_0, and it can be shown quantum mechanically that $\mu_0 = \sqrt{3}\mu$.)

The macroscopic moment $\vec{M}$ is parallel and proportional to the total angular momentum $\vec{A}$ of the system.

$$\vec{M} = \gamma \vec{A}.$$

γ is known as the *gyromagnetic ratio* of the system. The classical relation between the torque applied to a system possessing angular momentum and the rate of change of the angular momentum then gives the dynamic behavior of the molecular system.

$$\frac{d\vec{A}}{dt} = \text{Torque} = (\vec{M} \times \vec{H})$$

$$\frac{d\vec{M}}{dt} = \gamma(\vec{M} \times \vec{H}),$$

or

$$\frac{dM_x}{dt} = \gamma(M_y H_z - M_z H_y)$$

$$\frac{dM_y}{dt} = \gamma(M_z H_x - M_x H_z)$$

$$\frac{dM_z}{dt} = \gamma(M_x H_y - M_y H_x).$$

Take the direction of the (assumed large) static magnetic field along the z axis and assume that the microwave magnetic fields are in the $x-y$ plane. The spin energy of the system is then given by

$$W = -M_z H_z,$$

with a thermal equilibrium value of

$$W_{eq} = -M_{eq} H_z.$$

If the effects of relaxation processes are included in the above equations, they become

$$\frac{dM_x}{dt} = \gamma(M_y H_z - M_z H_y) - \frac{1}{T_2} M_x$$

$$\frac{dM_y}{dt} = \gamma(M_z H_x - M_x H_z) - \frac{1}{T_2} M_y$$

$$\frac{dM_z}{dt} = \gamma(M_x H_y - M_y H_x) - \frac{1}{T_1}(M_z - M_{eq}).$$

These are the famous equations first introduced by Bloch[13] to explain the phenomena of nuclear magnetic resonance.

Similar classical treatments can be given for the molecular amplification systems discussed later in this

[13] F. Bloch, "Nuclear induction," *Phys. Rev.*, vol. 70, pp. 460–474; October 1, 1946.

paper by introducing a *complex* electric or magnetic microwave susceptibility, the imaginary part corresponding to the absorption (or emission) of energy by the molecular system and the real part to the molecularly-induced dispersion. In general, however, the *microscopic* approach will be used in this paper as it gives a better detailed picture of the processes occurring.

III. Basic Amplifier and Oscillator Relations

In the preceding section, a discussion of the basic physical processes of importance in dealing with microwave amplification using the molecular interaction between matter and radiation was given. These ideas will now be applied to the microwave amplification or generation process itself, in particular, to the possible time-dependence of gain, the power handling capabilities, the available gain, the amplification bandwidth, the noise figure, and the efficiency of molecular amplifiers.

A. Continuous and Pulse Operation

The excitation process of the molecular system during which it is put into an emissive condition, *i.e.*, one in which there are more molecules in the upper of two microwave-coupled energy states, inevitably interferes with the amplification or oscillation process. Thus, if all molecules in the system are excited simultaneously only pulse operation[14] is possible, and each useful period of amplification or oscillation must be followed by a "dead" period while the system undergoes excitation. To achieve continuous operation, the various molecules constituting the macrosystem must undergo excitation at different times. The excitation process can occur either in the same region as the amplification process, or the molecules can be excited outside the interaction region and then brought into the amplification region. Each of the above possibilities is used in one or more of the devices to be discussed later.

In all molecular devices, both amplifiers and oscillators, power losses in the microwave structures are of great importance. To have an amplifier (or oscillator), it is essential that more power be transferred to the field from the molecular system than is lost (to resistive heating) in the structure. In a pulsed system, the state of the macrosystem is a function of time, and hence whether or not this condition for amplification is satisfied may also be time-dependent.

B. Saturation

As seen above (8) for absorption (it is also true for emission), the transfer of energy to the radiation field is proportional to the incident power, and hence the amplification is linear, as long as

$$\frac{T_1}{T_2}\left(\frac{pE}{h}\right)^2 \ll \left(\frac{1}{2\pi T_2}\right)^2$$

or

$$E \ll \frac{h}{2\pi p(T_1T_2)^{1/2}}. \tag{10}$$

Physically, linear amplification is only obtained when but a small fraction of the total available energy in a molecular system is extracted by induced emission. Thus, unless the strength of the transition-inducing microwave field satisfies the above condition, the amplifier will be operating in a nonlinear (saturated) fashion. As seen from (9), the frequency bandwidth for interaction (with no saturation) is related to the relaxation time by

$$(\text{Molecular bandwidth}) \lesssim \frac{1}{\pi T_2}.$$

Therefore, the condition for linearity of amplification is

$$E \ll \frac{h}{2p}\left(\frac{T_2}{T_1}\right)^{1/2} \times (\text{Molecular bandwidth}).$$

For electric dipole transitions, such as are common in a gaseous system, p is of the order of 10^{-18} esu[15] (1.6×10^{-29} coulomb-meters); for magnetic dipole transitions, as would be found in a paramagnetic amplifier, p is about 10^{-20} emu (10^{-23} joule-meter^2/weber). Thus, for linear amplification, the microwave fields must satisfy the conditions:

$$E\ (\text{electric dipole}) \ll 3\times10^{-9}\left(\frac{T_2}{T_1}\right)^{1/2} \times (\text{Molecular bandwidth})\ \text{stat-volts/cm}$$

$$\ll 10^{-4}\left(\frac{T_2}{T_1}\right)^{1/2} \times (\text{Molecular bandwidth})\ \text{volts/meter}$$

$$H\ (\text{magnetic dipole}) \ll 3\times10^{-7}\left(\frac{T_2}{T_1}\right)^{1/2} \times (\text{Molecular bandwidth})\ \text{Gauss}$$

$$\ll 3\times10^{-11}\left(\frac{T_2}{T_1}\right)^{1/2} \times (\text{Molecular bandwidth})\ \text{webers/meter}^2. \tag{11}$$

These conditions for linearity can be related to power flow into a cavity amplifier. For a solid-state (paramagnetic) amplifier at 10 kmc, for a bandwidth of 1 mc and $T_1 = T_2$, the microwave magnetic field strength in the cavity must be much less than a Gauss. This corre-

[14] A point of terminology arises here. It is always possible to gate a continuous amplifier (or oscillator) off and on, thereby achieving intermittent or "pulsed" operation. In this paper, however, the term "pulse operation" will not refer to such "gated continuous operation" but only to systems where the energy transfer to the field is intrinsically intermittent due to the mode of excitation.

[15] Gaussian units are used throughout this paper, *i.e.*, cgs electrostatic units (esu) for electric quantities and cgs electromagnetic units (emu) for magnetic quantities. This choice is made to conform with conventional usage in the literature of this field, where Gaussian units are almost invariably used.

sponds to a input power much less than a watt. As the example chosen represents a type of molecular amplifier that is relatively difficult to saturate, it is clear that low power handling capabilities should be expected in molecular amplifiers.

C. Gain

In considering the gain obtainable from a molecular amplifier, the physical situation must again be considered. A rough estimate for a cw amplifier consisting of a waveguide containing molecules in an emissive condition will first be given. For such an amplifier the molecules must have a proper phase relationship with the signal field or they will absorb rather than emit energy. Proper phasing can be assured by bringing the molecules into interaction with the signal field in the pure energy state ψ_2, corresponding to molecules in the upper energy level, rather than in a superposition energy state. Assuming that the signal to be amplified is on resonance, $\nu=\nu_0$, and is weak enough to avoid saturation effects, the average power emitted by each molecule is, from (8),

$$P = \frac{2\pi^2\nu p^2 E^2 T_2}{h}. \tag{12}$$

If N molecules contribute to the emission process, the total power is

$$P_{\text{total}} = \frac{2\pi^2 N\nu p^2 E^2 T_2}{h}.$$

The incident power in a waveguide is of the order of

$$P_{\text{inc}} = \frac{cAE^2}{8\pi}$$

where c is the velocity of light and A the cross sectional guide area. Since the power gain in an infinitesimal length of amplifier is proportional to the incident power, the wave will grow exponentially as it travels down the guide, past the emitting molecules. The gain can thus be written, neglecting guide attenuation, as

$$\text{Gain} = \exp(\alpha l)$$

where l is the length of the amplifier and the gain coefficient α is given by:

$$\alpha = \frac{P_{\text{emitted/cm}}}{P_{\text{incident}}} \approx \frac{16\pi^3\nu p^2 T_2 N_0}{hcA}. \tag{13}$$

Here N_0 is the number of molecules per unit length contributing to the emission, that is, in the upper state "excess." Under realizable conditions (for example, in the "hot-grid cell" discussed later), α may be of the order of 10^{-3} to 10^{-4} cm^{-1}. Thus, to get a gain of ten, an amplifier length of several meters is required.

Physically, (13) can be understood as follows. The gain increases with ν, as the energy given up by each interacting molecule (the "size" of each photon) is proportional to the frequency. Stronger coupling between the radiation field and the molecules as determined by the dipole moment p also results in higher gain, as does increased "excess population" of emissive molecules N_0. Finally, the longer the time T_2 a molecule interacts with the radiation field before it is disturbed, the greater the probability of its giving up its available internal energy as a photon and thus contributing to the amplification.

To avoid the practical difficulties associated with a long amplifier, a resonant structure such as a cavity that provides a long effective electrical path in a physically short length may be employed. If the molecular system is located in a resonant cavity, positive feedback is automatically built into the amplifier. It is well-known that the gain of such a regenerative amplifier can be arbitrarily large, becoming infinite at the threshold of oscillation. The actual situation may comprise a transmission cavity or a reaction cavity, with arbitrary couplings. A case particularly easy to analyze that displays many of the features of interest is that of a reaction cavity matched to the transmission line (Fig. 4). The output of the amplifier will be defined as the power leaving the cavity, and the input as the incident power. The behavior of such an amplifier can be seen in the following way.

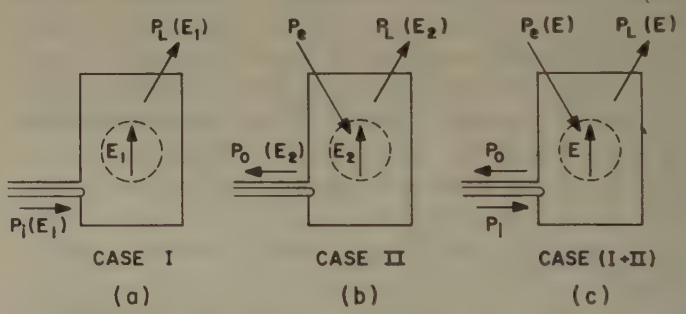


Fig. 4—Power and field relations in a matched reaction cavity amplifier. (a) A wave is incident on the cavity, building up an oscillating field E_1 in the cavity and being dissipated in resistive losses at the cavity walls. (b) An oscillating molecular system supplies power P_e in the cavity, building up a field E_2 and producing an outgoing wave, P_0. (c). The two cases are superposed.

Consider two situations:

1) Power P_i is incident on the cavity, which contains the molecular system, but the molecular interaction is effectively "turned off" by shifting the interaction frequency (*e.g.*, by "detuning" with a Stark[16] or Zeeman field). A resonant field of strength E_1 at the molecular system is built up in the cavity, and there are wall losses P_L. Since the cavity is matched, there is no outgoing wave. [See Fig. 4(a).] In this case

$$P_i = P_L = \frac{\nu V \overline{E_1^2}}{4Q_0} \tag{14}$$

[16] The shift in the energy of a molecular state due to an applied electric field is known as the Stark effect, after its discoverer. A similar shift of an energy level in a magnetic field is known as the Zeeman effect.

where $\overline{E_1^2}$ is the cavity field squared averaged over the cavity,

$$\overline{E_1^2} = k_0 \overline{E_1^2}, \tag{15}$$

V is the cavity volume and Q_0 is the unloaded cavity Q. k_0 is related to the "filling factor."

2) In this situation there is no incident wave, but the molecular system in the cavity is supplying energy to the field, setting up an oscillating field E_2. Now there is an outgoing wave P_0 and wall losses $P_L(E_2)$. [See Fig. 4(b).] These are related to E_2 by

$$P_0 = P_L = \frac{\nu V \overline{E_2^2}}{4Q_0}. \tag{16}$$

Let P_e be the power emitted by the molecular system. Then

$$P_e = P_0 + P_L.$$

Finally, superpose the two configurations so that the fields E_1 and E_2 are in phase [Fig. 4(c)]. Conservation of energy requires that

$$P_i + P_e = P_0 + P_L.$$

P_e and P_L are functions of the total field $E = E_1 + E_2$ in the cavity, whereas P_i is related only to the part E_1 and P_0 to the part E_2:

$$P_i(E_1) + P_e(E) = P_0(E_2) + P_L(E). \tag{17}$$

But

$$P_i(E_1) = \frac{k_0 \nu V}{4Q_0} E_1^2$$

$$P_0(E_2) = \frac{k_0 \nu V}{4Q_0} E_2^2$$

from (14), (15), and (16), while

$$P_L(E) = \frac{k_0 \nu V}{4Q_0} E^2.$$

To make the discussion definite, assume P_e has the Lorentz form given by (8):

$$P_e(E) = \frac{k_1 E^2}{(\nu - \nu_0)^2 + \left(\frac{1}{2\pi T_2}\right)^2 + \left(\frac{pE}{h}\right)^2}. \tag{18}$$

Defining

$$D \equiv \frac{k_0 \nu V}{4Q_0} \left(\frac{h}{p}\right)^2 \left[(\nu - \nu_0)^2 + \left(\frac{1}{2\pi T_2}\right)^2\right]$$

$$S \equiv \frac{k_1 h^2}{p^2}$$

$$e_i \equiv \frac{\left(\frac{p}{h}\right)}{\left[(\nu - \nu_0)^2 + \left(\frac{1}{2\pi T_2}\right)^2\right]^{1/2}} E_i,$$

the conservation of energy (17) becomes

$$De_1^2 + \frac{Se^2}{1 + e^2} = De_2^2 + De^2.$$

Defining further an "oscillation parameter" L:

$$L \equiv \frac{S}{2D} = \frac{2k_1 Q_0}{k_0 \nu V \left[(\nu - \nu_0)^2 + \left(\frac{1}{2\pi T_2}\right)^2\right]}$$

the equation becomes, using $e = e_1 + e_2$,

$$e^3 - e_1 e^2 + (1 - L)e - e_1 = 0. \tag{19}$$

Solutions of this equation, giving e, and hence e_2, as a function of e_1 for a fixed value of L can be easily, if tediously, found. The gain of the amplifier is given by

$$\text{Gain} = \frac{E_2^2}{E_1^2} = \frac{e_2^2}{e_1^2}.$$

Gain as a function of input power (actually e_1^2) is plotted in Fig. 5 for various L; output power (e_2^2) is

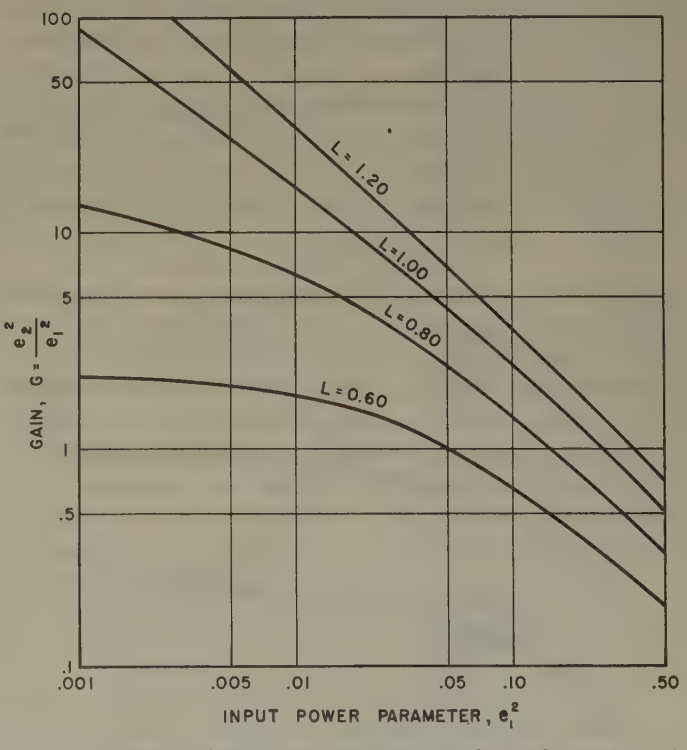


Fig. 5—Gain vs input power parameter e_1^2 for various values of oscillation parameter L for a matched reaction cavity amplifier. L is the ratio of power supplied by the (unsaturated) molecular system to twice the power lost resistively at the walls.

plotted against input power (e_1^2) in Fig. 6. Consideration of these figures shows that the optimal operating condition is with low e_1 (no saturation). In this limit, the gain is

$$\text{Gain (no saturation)} = \frac{L^2}{(1 - L)^2}. \tag{20}$$

When there is no incident power, (19) becomes

$$e^3 + (1 - L)e = 0$$

with the solutions $e=0$ and $e^2=L-1$. For $L<1$, the second solution is meaningless. However, for $L>1$, a finite real field can exist in the cavity, *i.e.*, oscillations can be sustained. Thus it is appropriate to call L the "oscillation parameter." The figures clearly show the saturation behavior at high incident fields where the gain falls off, eventually becoming less than one when the power supplied by the molecular system is unable to compensate for the large wall losses associated with the large cavity fields due to the large input wave. Eq. (20) for low power level gain shows the characteristic increase in gain (to infinity) as the oscillation parameter is increased to one.

It is similarly possible to analyze the case of a transmission cavity with arbitrary coupling, but this general case is mathematically rather unwieldy. Similarly, the details, but not the general picture, will be changed for a physical situation giving a relationship between molecularly emitted power P_e and microwave field strength E differing from (18).

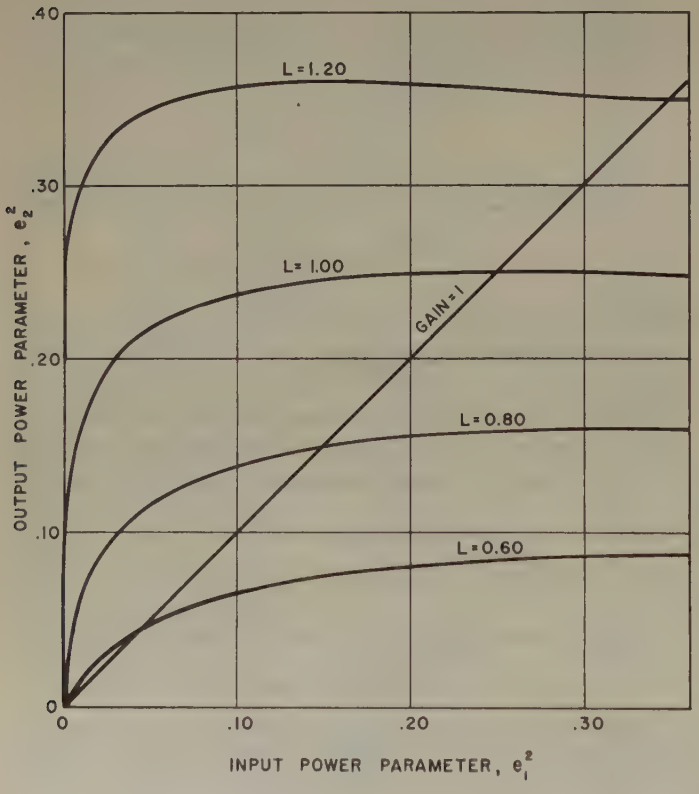


Fig. 6—Output power parameter e_2^2 vs input power parameter e_1^2 for various values of oscillation parameter L for a matched reaction cavity amplifier.

D. Bandwidth

Two factors influence the amplification bandwidth: the molecular relaxation processes and the microwave structure. (It is possible, of course, that the latter will also determine the former.) The relaxation processes determine what might be called the molecular bandwidth, which is the width of the resonance line as observed in ordinary absorptive spectroscopy. This width has been discussed earlier in Section II. The actual amplifier will have a somewhat narrower bandwidth, however.

To see this, consider the case of a nonresonant waveguide amplifier with a Lorentz molecular band-shape;

$$\text{Gain} = \exp(\alpha l)$$

and

$$\alpha = \frac{\text{const.}}{(\nu - \nu_0)^2 + \left(\frac{1}{2\pi T_2}\right)^2}.$$

Defining the bandwidth as the frequency interval between the points where the gain is one-half its maximum value, it is readily shown that

$$\text{(Amplification bandwidth)} = \left[\frac{\ln 2}{\ln \frac{(\text{Gain})_{\max}}{2}}\right]^{1/2} \times \frac{1}{\pi T_2}$$

$$= \left[\frac{\ln 2}{\ln \frac{(\text{Gain})_{\max}}{2}}\right]^{1/2} \times \text{(Molecular bandwidth)}.$$

Similarly, for the case of a matched-cavity amplifier with a Lorentz-type resonance, from

$$\text{Gain} = \frac{L^2}{(1 - L)^2}$$

and the oscillation parameter L,

$$L = \frac{\text{const.}}{(\nu - \nu_0)^2 + \frac{1}{(2\pi T_2)^2}},$$

assuming high gain, *i.e.*, $L \approx 1$, it can be shown that

$$\text{(Amplification bandwidth)} = \frac{(\sqrt{2} - 1)^{1/2}}{(\text{Gain})^{1/4}} \times \text{(Molecular bandwidth)}$$

$$= \frac{0.644}{(\text{Gain})^{1/4}} \times \text{(Molecular bandwidth)}.$$

The above expressions show that the gain-bandwidth product is not constant, but increases with increasing gain. For reasonable gains ($10 \leqq \text{Gain} \leqq 100$), bandwidths between one-fifth and two-thirds the "molecular width" may be expected.

One of the greatest limitations on molecular amplifiers is the difficulty of getting useful bandwidths. From the discussion of Section II, the molecular bandwidth is inversely proportional to the relaxation time. Eq. (13) shows that the gain increases with frequency, dipole

moment, relaxation time, and density of "active" molecules. If the bandwidth is increased by shortening the relaxation (or interaction) time in some way, the gain will fall off unless there are compensating changes in either frequency, dipole moment, or molecular density. The possible range of these parameters must thus be considered.

In an amplifier where the molecular system is gaseous, electric dipole transitions, which are much stronger than magnetic dipole transitions, can be used. However, dipole moments are of the order of 10^{-18} esu (1.6×10^{-29} coulomb-meters) whatever the gas used; varying the gas molecule used will not appreciably alter p. It might be thought that if in a gas amplifier gas collisions are the dominant relaxation mechanisms, any desired bandwidth could be achieved by increasing the density, since T_2N_0 is independent of pressure.

$$\left(T_2 \sim \frac{1}{N_0}, \text{ so bandwidth} \sim N_0\right).$$

In theory this is so; in practice, excitation mechanisms fail to work at high gas pressures. This at present provides an upper limit to expected bandwidths of under 100 kc. Some improvement can be expected by going to molecular resonances at higher frequencies. However, increased losses in the associated microwave circuits tend to reduce the gain obtained in this way.

Another possible way of increasing bandwidth is to use solid (or liquid) molecular systems, with their huge increases in density over gaseous systems. This can compensate for the gain lost by spreading the molecular emission energy over a greater range of frequencies, and greater bandwidths can be obtained this way; however, there are important counterbalancing effects to be considered. One is that in condensed systems magnetic dipole transitions must be used, as the strong, rapidly fluctuating electric fields encountered in liquids and solids relax electric dipole-coupled systems so rapidly that they cannot be excited with presently-available techniques. The largest magnetic dipoles found are of the order of a Bohr magneton, or

$$10^{-20} \text{ emu} \left(10^{-23} \frac{\text{joule-meter}^2}{\text{weber}}\right).$$

Since the dipole moment enters as the square, whereas the relaxation time enters only as the first power in the gain coefficient expression (13), a density increase of 10^4 is required just to counterbalance the effects of the weaker dipole moment.

Even with magnetic dipoles, relaxation times may be unusably short. At present, paramagnetic materials seem the most promising, the paramagnetism arising from unpaired electron spins. The energy levels determining the resonance frequency are generally in this case associated with the Zeeman energy of the two possible spin orientations with respect to an external applied magnetic field. The transition frequency is given by

$$\nu = \frac{g\mu_B H}{h} \equiv \gamma H.$$

Here g is the spectroscopic splitting factor and $\mu_B = 9.27\times10^{-21}$ erg/Gauss (9.27×10^{-24} joule-meter^2/weber) is the Bohr magneton. For paramagnetic spin systems with usable relaxation times, $g \approx 2$. This gives a frequency of

$$\nu = 2.8H \text{ mc}$$

where H is in Gauss.[17] To avoid seriously broadening the resonance by magnetic field inhomogeneities, it is necessary to have a field uniform over the sample to a fraction of a per cent of the total field. An additional advantage of a paramagnetic amplifier over a gaseous one is that the frequency is readily controllable by means of the applied magnetic field.

E. Noise Figure

It was pointed out in the introduction that one of the important properties of molecular amplification is that it may introduce very little additional noise onto a signal. To see this, an expression for the noise figure of a waveguide-type of molecular amplifier will now be derived. Other discussions of molecular amplifier noise have been given in the literature.[1,18]

Referring to Fig. 7, let P_s be the signal power in a wave traveling to the right at position x, and P_N the corresponding noise power (in a unit frequency band about the frequency of P_s). In a length of amplifier dx, the increase in signal power dP_s is given by

$$dP_s = (N_2 - N_1)\Gamma P_s dx - \alpha_g P_s dx. \qquad (21)$$

Here N_2 is the number of molecules in the upper energy state per unit length, N_1 the number in the lower state per unit length, α_g is the waveguide attenuation coefficient, and Γ is a constant depending on the dipole matrix element for the transition and the guide geometry and mode. The first term on the right-hand side of (21) represents the molecular amplification (increase in signal power due to excess of stimulated emission over

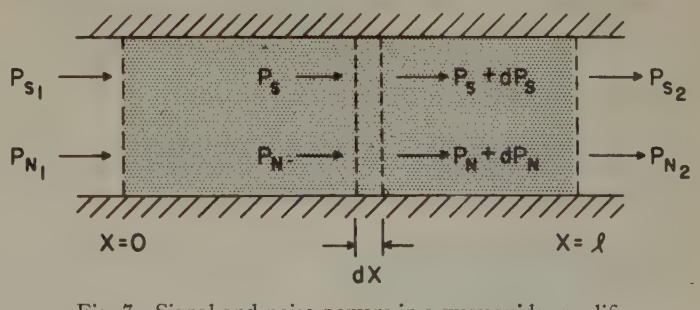


Fig. 7—Signal and noise powers in a waveguide amplifier.

[17] It should be noted that nuclear magnetic moments could in principle be used instead of electronic moments. However, the γ's corresponding to nuclear moments are two to three orders of magnitude smaller than the electronic $\gamma = 2.8$ mc/Gauss, and thus magnetic fields in the 10^5–10^6 Gauss range are necessary to put the transition frequency in the microwave range.

[18] K. Shimoda, H. Takahasi, and C. H. Townes, "Fluctuations in amplification of quanta" (to be published).

absorption) and the second the reduction in signal power due to resistive losses in the walls.

A similar expression can be written for the increment of noise power:

$$dP_N = (N_2 - N_1)\Gamma P_N dx - \alpha_g P_N dx + \alpha_g P_{N0} dx + \beta N_2 dx. \quad (22)$$

The first two terms on the right here are exactly analogous to the terms in the signal power expression. There are two additional terms, however. The first of these, $\alpha_g P_{N0} dx$, represents black-body radiation from the walls. The subscript 0 refers to a condition of thermal equilibrium at the wall temperature T_0, taken to be room temperature. The second additional term, $\beta N_2 dx$, represents the effects of spontaneous incoherent emission: it is proportional to the number of molecules in the upper energy state. (The proportionality constant β, like Γ, depends on the dipole moment and guide geometry.)

The relationship between β and Γ can be determined by considering the special condition of thermal equilibrium. Then $dP_N = 0$, and (22) becomes

$$0 = (N_{20} - N_{10})\Gamma P_{N0} dx - \alpha_g P_{N0} dx + \alpha_g P_{N0} dx + \beta N_{20} dx$$

or

$$\beta = \left(\frac{N_{10}}{N_{20}} - 1\right)\Gamma P_{N0}.$$

But

$$\frac{N_{20}}{N_{10}} = \exp\left(-\frac{h\nu}{kT_0}\right),$$

from (4), and the Planck distribution law for black-body radiation gives

$$P_{N0} = \frac{h\nu}{\exp\left(\frac{h\nu}{kT_0}\right) - 1}.$$

From these is obtained the relationship between β and Γ:

$$\beta = h\nu\Gamma.$$

Rewriting (22) using this relation gives

$$dP_N = [(N_2 - N_1)\Gamma - \alpha_g]P_N dx + (h\nu\Gamma N_2 + \alpha_g P_{N0})dx.$$

This can be directly integrated to give

$$\frac{P_{N2} + \dfrac{h\nu\Gamma N_2 + \alpha_g P_{N0}}{(N_2 - N_1)\Gamma - \alpha_g}}{P_{N1} + \dfrac{h\nu\Gamma N_2 + \alpha_g P_{N0}}{(N_2 - N_1)\Gamma - \alpha_g}} = \exp\{[(N_2 - N_1)\Gamma - \alpha_g]l\}$$

where P_{N2} is the noise power out of the amplifier, P_{N1} is the noise power input, and l is the amplifier length. Similarly integrating (21) for the signal power, the power gain is

$$\text{Gain} = \frac{P_{S2}}{P_{S1}} = \exp\{[(N_2 - N_1)\Gamma - \alpha_g]l\}.$$

The gain may be written as

$$\text{Gain} = \exp[(\alpha - \alpha_g)l]$$

where α is the "gain coefficient."

Define

$$M \equiv \frac{h\nu\Gamma N_2 + \alpha_g P_{N0}}{(N_2 - N_1)\Gamma - \alpha_g}.$$

Then

$$\text{Gain} \equiv G = \frac{P_{N2} + M}{P_{N1} + M}$$

or

$$\frac{P_{N2}}{P_{N1}} = G + (G - 1)\frac{M}{P_{N1}}.$$

The noise figure F of the amplifier is defined by

$$F \equiv \frac{P_{N2}}{GP_{N1}} \quad \text{for} \quad P_{N1} = P_{N0}.$$

Thus,

$$F = 1 + \left(1 - \frac{1}{G}\right)\frac{M}{P_{N0}}.$$

M can be put in the form

$$M = \frac{h\nu}{1 - \dfrac{N_1}{N_2}}\left(1 + \frac{\alpha_g}{\alpha - \alpha_g}\right) + \frac{\alpha_g P_{N0}}{\alpha - \alpha_g}$$

and

$$F = 1 + \left(1 - \frac{1}{G}\right)\left[\frac{h\nu}{P_{N0}}\frac{\left(1 + \dfrac{\alpha_g}{\alpha - \alpha_g}\right)}{\left(1 - \dfrac{N_1}{N_2}\right)} + \frac{\alpha_g}{\alpha - \alpha_g}\right].$$

In the case $G \gg 1$, this can be factored into two terms:

$$F = \left[1 + \left(\frac{N_2}{N_2 - N_1}\right)\frac{h\nu}{P_{N0}}\right]\left[1 + \frac{\alpha_g}{\alpha - \alpha_g}\right]. \quad (23)$$

The first term on the right is the contribution to the noise figure due to spontaneous incoherent emission, the second, the contribution of the effects of black-body radiation in the guide. The two terms are closely related, however as the gain coefficient α and the term

$$\left(\frac{N_2}{N_2 - N_1}\right)$$

both depend on the "excess population" in the upper state produced by the excitation process. This expression also shows clearly that losses are vitally important: unless $\alpha \gg \alpha_g$, the amplifier will have a poor noise figure.

It is also clear that a large class of "paired off" molecules adversely affects the noise figure by increasing N_2 without increasing N_2-N_1. However, if the gain coefficient α greatly exceeds the attenuation coefficient α_s and there are few molecules N_1 in the lower state,

$$F \approx 1 + \frac{h\nu}{P_{N0}} \approx 1 + \frac{h\nu}{kT_0}$$

which is of the order of 1.004, or a noise figure of 0.02 db.

F. Efficiency

In general, the efficiency of molecular amplifiers is low. If the over-all efficiency is defined as the ratio of the increase of microwave power in the amplifier to the total power expended in associated electronic circuits, etc., as well as in the molecular system, the efficiency is invariably low (well under one per cent). The reasons for this vary with the different means of exciting the molecular systems, and hence can only be properly discussed in connection with an excitation method. However, a few general considerations will indicate that high efficiency is not to be looked for in molecular amplifiers.

Roughly speaking, energy must be supplied to each molecule at a rate given by

$$P_{\text{in}} \approx \frac{h\nu}{T_1}$$

where ν is the amplification frequency. The power transferred to the radiation field from the molecular system is, from (12),

$$P_{\text{out}} \approx \frac{2\pi^2\nu p^2 E^2 T_2}{h}.$$

The efficiency is thus of the order of

$$\text{Efficiency} = \frac{P_{\text{out}}}{P_{\text{in}}} \approx 2\pi^2 T_1 T_2 \left(\frac{pE}{h}\right)^2.$$

The condition for linear amplification is that (10)

$$\left(\frac{pE}{h}\right)^2 \ll \frac{1}{4\pi^2 T_1 T_2}.$$

So

$$\text{Efficiency} \ll 1/2.$$

From this it is seen that the requirement of linear amplification severely limits the efficiency that can be expected.

IV. Practical Approaches

Having discussed molecular amplifiers in general, various devices that apply the idea of emissive molecular interaction to solve the practical problems of low-noise amplification, the generation of microwaves, and production of frequency standards of high constancy ("atomic clocks") will now be considered.

A. Molecular-Beam Maser

The various devices developed as molecular amplifiers differ mainly in the way in which an emissive condition is obtained. A discussion of amplifiers in a sense thus becomes a discussion of excitation methods. One well-known type of molecular amplifier is the ammonia-beam Maser.[1,19] Here the excitation method consists of physically separating a beam of gas molecules into two beams, one containing the lower state, and one the upper state emissive molecules. After the separation, the emissive beam is used in an amplifier cavity.

The Maser is shown schematically in Fig. 8(a). The gas molecules issue from the source (a chamber maintained at an ammonia pressure of a few millimeters of mercury) as a well-collimated beam, the directivity being obtained by the means of a source opening consisting of channels which are long compared to their diameter and short compared to the mean free path of the gas. This beam travels first through a focuser [Fig. 8(b)] and finally into the resonant cavity. The focuser removes from the beam the molecules in the lower of the two energy states of interest, leaving in the beam entering the cavity only upper state molecules.

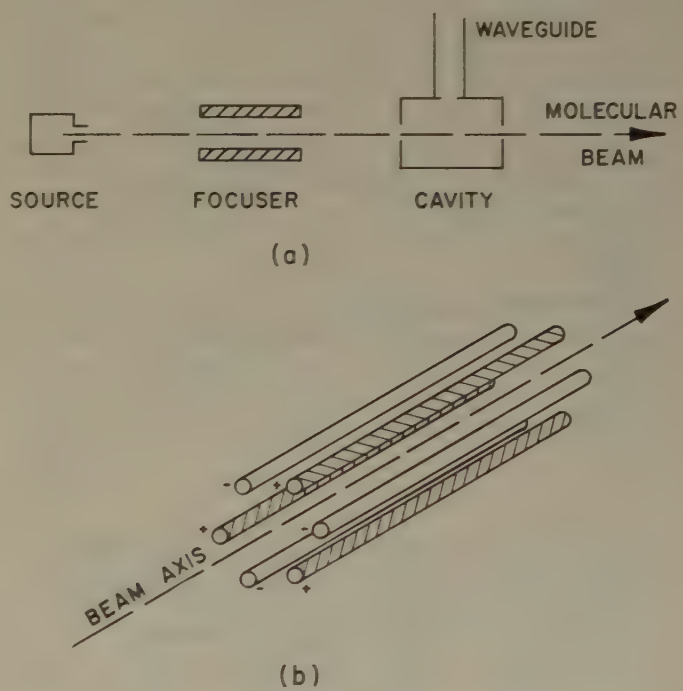


Fig. 8—(a) Schematic diagram of a molecular beam Maser. (b) A perspective view of the focuser.

The action of the focuser can be understood by reference to Fig. 9. This shows how the energies of the internal states of the molecules vary in an electric field; it is

[19] J. P. Gordon, "Hyperfine structure in the inversion spectrum of $N^{14}H_3$ by a new high-resolution microwave spectrometer," *Phys. Rev.*, vol. 99, pp. 1253–1263; August 15, 1955.
K. Shimoda, T. C. Wang, and C. H. Townes, "Further aspects of the theory of the Maser," *Phys. Rev.*, vol. 102, pp. 1308–3121; June 1, 1956.
J. C. Helmer, "Theory of a Molecular Oscillator," Microwave Lab. Rep. no. 311, Stanford Univ., Stanford, Calif.; June, 1956.

seen that the energy of the upper state increases in a field, and the energy of the lower state decreases. Because of this (quadratic) Stark effect on the energy levels, a molecule placed in a region where the electric field has a gradient will experience a force; this will be toward the low field region for a molecule in the upper energy state, but toward the high field region for a lower state molecule. An inhomogeneous field region thus acts on the original beam of molecules so as to split it into two physically separated beams, a focused one consisting of upper-state molecules and a diffuse, deflected one of lower-state molecules. The inhomogeneous field is produced in the focuser by a series of long, thin electrodes, parallel to the beam axis and surrounding it [see Fig. 8(b)]. Alternate electrodes are charged to high and low potentials: this produces zero field along the axis and high fields near the electrodes. The upper state molecules in the beam thus experience a focusing force toward the beam axis, while the lower state ones are defocused out of the beam. Clearly, only molecules having this type of Stark effect can be used in the Maser.

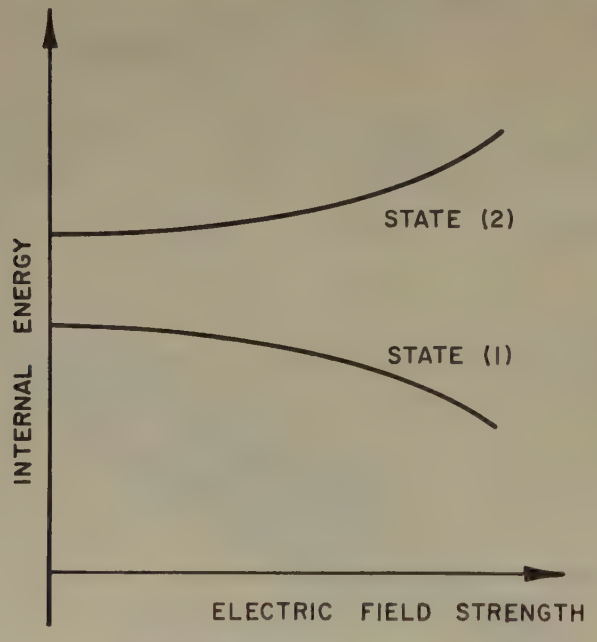


Fig. 9—Stark effect in an ammonia molecule.

If the power emitted by the molecules exceeds the losses in the walls, the device can act as an amplifier. If the power emitted exceeds the sum of wall losses and the power coupled out of the cavity into the connecting waveguides, oscillations will build up until saturation effects make the molecularly emitted power equal to all losses. The power emitted can be controlled by varying the beam density. Since it is possible to get beam densities high enough to sustain oscillations, the gain as an amplifier can be made essentially infinite, with, of course, a corresponding decrease of the amplification bandwidth to practically zero.

The bandwidth of the Maser is determined by a process not previously discussed. Since the beam is tenuous, gas collision broading is absent, and if the TM_{010} mode in a cylindrical cavity is used, there is no axial variation in the microwave fields and Doppler effects are also missing. The coherent interaction time is then determined by the transit-time; *i.e.*, the time it takes for a molecule to travel the length of the cavity. The "molecular bandwidth" is of the order of[20]

$$(\text{Molecular bandwidth}) \approx \frac{1}{T_2} \approx \frac{v}{l},$$

where l is the cavity length and v the mean molecular velocity.

In a molecular-beam Maser, the internal energy emitted as microwave energy is acquired during the collisions of the molecules with the walls of the source chamber whereby they come into thermal equilibrium with this chamber. The kinetic energies of motion of the molecules arise in the same way. If the gas admitted to the source chamber is already at the temperature of the chamber, there is no further transfer of energy to the gas from the chamber.

When the Maser is acting as a linear amplifier, only a small fraction (a few per cent) of the total internal molecular energy is transformed to microwave energy, and hence the Maser efficiency is low. Acting as an oscillator, some nonlinearity of emission is inherent, and the efficiency can be somewhat higher. The kinetic energy of the molecules is not converted to microwave energy, but is lost when the "spent" gas is pumped away after traversing the amplifier cavity. If this is included in calculating the efficiency, the efficiency is low indeed, tas the kinetic energy of a molecule leaving a source a room temperature is typically hundreds of times its total internal energy available for conversion to microwaves.

One gas suitable for use in a Maser is ammonia: here the "inversion" transitions provide suitable pairs of levels for focusing. The strongest set of levels has a transition frequency at 23.870 kmc (1.26 cm). Cavities roughly 10 cm long give a transit-time bandwidth of about 6 kc; the amplification bandwidth is somewhat smaller, depending on the amplifier gain. Assuming a loaded cavity $Q_L = 5000$ and unloaded $Q_0 = 10{,}000$, the saturation condition for linear amplification (11) indicates that the incident signal power must be

$$P_{\text{inc}} < 10^{-10} \text{ watts.}$$

Another important property of the Maser is its noise figure. However, it is extremely difficult to measure noise figures as low as expected for such an amplifier, and no conclusive measurements have been made. The measurements made indicated a Maser noise figure of about one; *i.e.*, zero db.

[20] A suitable average over the distribution of velocities must of course be taken, but this only introduces a numerical factor of order one.

As an oscillator, the Maser has the very high spectral purity to be expected of a very narrow band amplifier. (The molecular bandwidth is about 3 parts in 10^7 of the central frequency, giving an amplification bandwidth of only a few kilocycles.) Experimentally,[1] a spectral purity of about *4 parts in* 10^{12} has been obtained for a period of the order of one second. The power generated by the device when oscillating was estimated to be a few times 10^{-10} watts.

The questions arise: what can be done to improve various operating characteristics, or, alternatively, to what extent can performance in one respect be enhanced at the cost of worsened behavior in another characteristic? As an amplifier, the main characteristics desired are high gain, broad bandwidth, low noise figure, and high power handling capabilities. As an oscillator, spectral purity and power are wanted. High gain in the Maser is easily assured. The amplification bandwidth can be increased if the transit time is reduced. This is most readily accomplished by shortening the cavity in the direction of beam travel. However, unless the beam geometry is altered, this reduces the number of molecules in the cavity at any one time and hence reduces the power emitted by the molecules. Unless the cavity losses are cut proportionately, the available gain is thereby reduced and the noise figure increased. One way to maintain a high number of molecules in a shortened cavity is to use multiple beams, but this introduces serious problems of pumping and obtaining a high cavity Q. Gain can also be traded for increased bandwidth by increasing the coupling of the cavity to the waveguide (reducing the loaded Q_L). The bandwidth can be increased by either method without loss of gain if the beam flux can be increased. Oscillator power can also be increased by increasing the flux. Considerable effort is being made to improve gas sources to increase beam densities.

There are several other practical problems in connection with the Maser that are receiving attention. Improvement of focusing methods is one. Also, since molecules must pass from the source through the focuser and cavity without colliding with other molecules, a high vacuum is needed, and various improved pumping schemes are under consideration. With its high spectral purity and its frequency basically determined by molecular properties, the Maser should provide a good atomic frequency standard. However, the exact frequency of oscillation can be "pulled" slightly by the resonant cavity or by stray fields. Various methods of eliminating or allowing for such pulling effects are being studied. Finally, the question of the tunability of a Maser amplifier arises. As seen above, the energy separation of the two states, and hence the molecular transition frequency, can be altered by an electric field. A magnetic field can have a similar result. However, problems of uniformity of tuning field (and degeneracy-splitting effects) make it practically impossible to change the resonance frequency more than a megacycle by these methods; the molecular beam Maser is essentially untunable.

B. Hot Grid State Separator

Another type of molecular amplifier is the "hot grid cell" devised by Dicke.[21] The way a gas is maintained in an emissive condition in this device can be seen with reference to Fig. 10. Fig. 10(a) is a schematic cross section of one configuration of such a device. The microwave structure consists of a plane parallel plate waveguide, the plates being labeled "cold wall" and "hot wall" for a reason that will shortly become clear. The microwave fields are assumed to be in the form of a wave propagating between these conducting plates and into the plane of the paper. Adjacent to the hot wall is a grid of fine wires parallel to the hot wall and each other, and maintained at a high voltage with respect to the hot wall. This produces a region of intense electrostatic field around the wires and along the hot wall. In the following, it is assumed that the grid is completely transparent to gas molecules, to simplify the discussion. This clearly is only an approximation. However, by heating the grid structure itself, it becomes an "equivalent hot wall" and itself behaves as the actual hot wall. The region between the walls is filled with a gas, such as ammonia, that has a Stark effect as shown in Fig. 6, and is at a pressure such that the mean free path for gas-gas collisions is several times the distance between walls. Such collisions can thus be neglected. Fig. 10(b) shows the distribution of electric field strength in the cell; Fig. 10(c) is a plot of internal energy of a gas molecule as a function of position in the cell for molecules in the upper and lower of the two energy levels of interest. It is seen that in the bulk of the cell, between the cold wall and grid, there is no electric field (other than the microwave field) and the two energy levels are separated by the usual amount, $\Delta W = h\nu_0$, where ν_0 is the frequency of the microwave field at resonance.

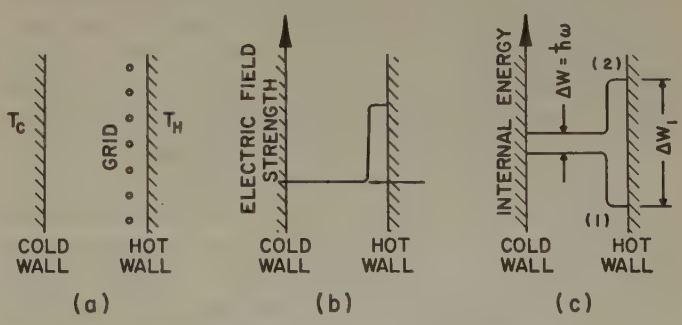


Fig. 10—Temperature, electric field strength, and internal energy as a function of position across a hot grid separation cell.

Gas molecules that strike the cold wall become "thermalized" at its temperature T_C. This means that they leave the wall with velocities characteristic of a Max-

[21] R. H. Dicke, private communication.

wellian distribution at T_C, and with a distribution between the two internal energy levels given by (4), with $T=T_C$. Thus the class of molecules moving toward the right after striking the cold wall contains more molecules in the lower energy state than the upper, and has a net absorptive effect. As the molecules move toward the hot wall, those in the upper energy state see a repulsive barrier in the region of high electrostatic field and tend to be reflected back toward the cold wall. Molecules in the lower state are attracted into the potential energy well along the hot wall [Fig. 10(c)] and hence strike the hot wall (or hot grid structure).

The height of the repulsive barrier seen by the upper state molecules depends on the strength of the electric field; however, with a Maxwellian distribution of velocities, some upper state molecules will possess sufficient kinetic energy to surmount the barrier and strike the hot wall, regardless of barrier height. The molecules that are reflected back to the cold wall form a second, smaller class of molecules; this class, composed as it is of upper state molecules only, is strongly emissive.

A third group of molecules consists of those leaving the hot wall and returning to the cold wall. These molecules leave the hot wall in equilibrium with it at its temperature T_H. However, the energy difference ΔW_1 between the two states in the strong field at the wall is much greater than $\Delta W=h\nu_0$, and so, by (4), many more molecules leave the hot wall in the lower energy state than in the upper. Now it is the lower state molecules that have to surmount a Stark field barrier to return to the cold wall, while the field accelerates the upper state molecules in their return journey. The net result is that this third group of molecules, containing both upper and lower state molecules, is absorptive; *i.e.*, has a higher density of lower than of upper state molecules in it.

The net effect of these three groups of molecules depends on T_C, T_H and the height of the electrostatic field barrier. If $T_C=T_H$, the gas in the field-free region between the "cold" wall and grid is in thermal equilibrium with the walls, and hence is absorptive, regardless of the high-field region. However, if the temperature of the cold wall is lowered, $T_C<T_H$, two effects occur. One is that the proportion of molecules in the lower state leaving the cold wall increases, by (4). This is a relatively unimportant effect. Lowering T_C has the more significant result that the kinetic energies of the molecules leaving the cold wall are reduced, and more of these slower molecules are reflected at the field barrier, increasing the number of molecules in the emissive, reflected class. Raising the hot wall temperature T_H has a similar result, for different reasons. By increasing T_H, more molecules leaving the hot wall are in the upper energy level [from (4)]. There is also the result that the molecules returning from the hot wall are speeded up by raising T_H, and since this is an absorptive class of molecules, by thus decreasing their transit time to the cold wall, their density, and hence absorptive effect, is reduced for a constant molecular flux. The net result can be that, for suitable T_C, T_H, and field barrier height, the gas is maintained in an emissive condition in the main part of the cell.

An exact analysis of such a grid cell is exceedingly difficult, as it depends on suitable averages to determine such parameters as the "effective field barrier height," a spatial average over the inhomogeneous field produced by the grid structure. However, estimates indicate that the "excess population," (N_2-N_1), can be of the order of one per cent of the total number of molecules for temperatures of the order $T_C\approx -100°\text{C}$, $T_H\approx 200°\text{C}$, and fields produced by appropriate grid structures at 15–20 kv voltages. This corresponds to a gain coefficient (13) of the order of $\alpha\approx 10^{-3}$ cm^{-1}. This is too small to make a nonresonant waveguide amplifier practical: an amplifier many meters long would be required to produce useful gain. It is nevertheless large enough to make a low-noise amplifier possible using a resonant cavity type of microwave structure; as seen above, with a cavity amplifier, the gain can be made arbitrarily large (with an unavoidable loss of bandwidth).

It might be expected that transit time effects across the cell would determine the amplification bandwidth. This however is not the case. For satisfactory operation of the cell, a rectangular cell cross section is desirable. To make a very low loss cavity with this geometry, one several wavelengths long is required. In this case, Doppler effects cannot be neglected, and indeed provide the dominant broadening mechanism. For ammonia as the active gas, the Doppler-determined molecular line breadth is of the order of 50 kc, about an order of magnitude larger than for a beam-type Maser. This greater bandwidth is accomplished without loss of gain, despite the small fractional upper state enrichment, by the much higher molecular densities achieved with the hot-grid cell compared with the molecular beam Maser.

The Maser, with its narrower bandwidth, is expected to be much more stable as an oscillator than the hot-grid cell. Thus, for frequency standard applications the beam type of device is to be preferred. On the other hand, the hot-grid cell can be operated as a sealed-off device without the continual supply of gas and its subsequent removal as in a beam amplifier.

The efficiency of a hot-grid cell is low. In addition to the loss taken to preserve linear operation, the thermal losses as the molecules travel from hot wall to cold are enormous relative to the microwave energy conversion. (Here again, as in the beam Maser, the internal energy comes from the thermal energy of the cell walls.)

An amplifier operative on the hot-grid state separation principle is under active investigation at RCA Laboratories at the present time.

C. Pulse Inversion

One of the methods of achieving an emissive state discussed above is essentially a continuous process,

i.e., the hot-grid cell. The other, molecular-beam separation of states, while separating the exciting region from the utilization region, nonetheless uses a continuous flow of gas to achieve effectively cw operation. There are, however, other means of exciting a molecular system that are distinctly pulse-operation approaches. "Pulse inversion of states" is one of these. From (6) it follows that if a system is exposed to a pulse of microwave power on resonance ($\nu=\nu_0$) of such strength and duration that

$$\frac{pET}{h}=\frac{1}{2}, \tag{24}$$

molecules originally in the lower state will be raised to the upper state and vice versa; *i.e.*, the state populations will be *inverted*. Thus, such a pulse transforms an absorptive system into an emissive one. The pulse duration must be short compared to the relaxation times, or complete inversion is not achieved. This is not a serious limitation, however, as with readily available powers, pulses of under a microsecond duration satisfy (24). Two conditions are critical in this method of obtaining an emissive state: 1), if the pulse frequency is off resonance, complete inversion will not be obtained [see (6)], and 2), the product of pulse strength and duration must be accurately adjusted.

An amplifier can be made by putting a molecular system in a suitable microwave structure such as a resonant cavity and exciting it with an inverting pulse. For a period of time given by the relaxation processes, the cavity with its emissive loading will amplify microwave signals incident upon it in a frequency bandwidth corresponding to the gain bandwidth of the amplifier.

This excitation method offers the possibility of relatively high efficiency, on a molecular basis, if a system with $T_1 \gg T_2$ is used, and some time-dependence of the amplifier gain is allowed. Apart from resistive losses in the microwave structure, much of the energy supplied in the excitation pulse can be re-extracted in the amplification period. However, if the power requirements of the electronic devices needed to generate and control the inverting pulses are included in the calculation, even this excitation scheme results in low efficiency.

Such a device has obvious faults as an amplifier. It only amplifies for a fraction of the time, and is nonamplifying in the excitation and the "thermalization" period in which equilibrium is again attained before the next inverting pulse. The gain is therefore periodically varying. If the device operates at room temperature, the noise figure cannot be better than 3 db, from (23). This can be improved by going to low operating temperatures; at liquid helium temperatures, the minimum noise figure is under 0.1 db. A serious fault of this method of achieving state-population inversion is that it depends on a critical adjustment of frequency and pulse strength and duration. Means of overcoming these difficulties will be discussed in connection with a second pulsed method of obtaining an emissive state.

D. Inversion by Adiabatic Fast Passage

Bloch[14] has shown that spin systems in a static magnetic field can be inverted by what is called *adiabatic fast passage*. His results can be generalized[22] to show that state populations in an arbitrary two-level system can be inverted by a similar technique. In adiabatic fast passages, the molecular system is subjected to a strong microwave field of amplitude E and variable frequency. The frequency of this field starts far off resonance and is slowly swept through the resonant frequency until it is far off resonance on the other side. When this has been done, the state populations are inverted. Three conditions must be met for this to occur:

1) The passage must be adiabatic; that is, the frequency must be changed slowly compared to the internal motions of the molecule in response to the driving field E. This condition can be expressed as

$$\frac{d\nu}{dt} \ll \frac{pE}{h}.$$

2) The passage must be fast compared to the relaxation time; the time τ_s required to sweep the frequency from one side of resonance to the other must be short compared to the relaxation time τ_r of the system.

$$\tau_s \ll \tau_r.$$

3) The driving field E must be larger than the maximum radiation field of the system. During the passage through resonance, the molecular system develops an oscillating dipole moment; the maximum radiation field of this moment must be smaller than the driving field or population inversion cannot be achieved.

A physical explanation can be given for each of these requirements. In an adiabatic fast passage, the molecular system goes through a series of quasi-stationary states. If the sweep rate is too large, the system cannot follow the changes adiabatically, and nonstationary states, such as are responsible for pulse inversion, are induced. The second condition merely assures that the inversion is completed before the competing relaxation processes can restore the system to thermal equilibrium. The third condition arises because the radiation field and driving field become out of phase as they approach each other in magnitude, and at equality of magnitudes, they just cancel each other in their effects.

Two other points of importance should be mentioned. One is that it does not matter in which direction the frequency sweep traverses the resonance: the initial frequency can be either above or below the resonant frequency. The second is that, if the resonant frequency of the molecular system can be altered by the application or change of an applied electric or magnetic field, for example, the inversion can be achieved by keeping the frequency of the applied microwave field fixed and *sweeping the resonant frequency* from one side of the applied frequency to the other.

[22] S. Bloom, private communication.

Adiabatic fast passage has two major advantages over pulse inversion as a method of achieving an emissive state: it is not necessary to control the frequency of the microwave exciter source accurately, and the exact duration and time dependence of the frequency sweep are similarly uncritical. The other difficulties of pulse inversion enumerated above are also met in adiabatic fast passage. However, as mentioned earlier, most, if not all, are susceptible to amelioration. Before discussing this, the characteristics desirable in a molecular system excited by adiabatic fast passage will be considered.

From (13), the gain coefficient α increases with the number of "excess" molecules N and the dipole moment p, and decreases with increasing molecular bandwidth as

$$\alpha \sim \frac{p^2 N}{(\text{Bandwidth})}.$$

Since amplification bandwidth is at a premium, it is clear that systems with a large "excess" population are desirable: if state population inversion is to be used, a large excess at thermal equilibrium is wanted. From (5a), $N_1 - N_2 = N \tanh (h\nu/2kT)$, a large excess can be obtained in two ways, by increasing the molecular density or by going to lower temperatures.

Low temperatures are also desirable from a noise figure point of view, as is seen by considering (23). Neglecting guide losses,

$$F_{\min} = 1 + \left(\frac{N_2}{N_2 - N_1}\right)\frac{h\nu}{P_{N0}}.$$

Starting from a state of thermal equilibrium at a temperature of the molecular system T_{molec}, after state inversion

$$\frac{N_2}{N_1} = \exp\left(+\frac{h\nu}{kT_{\text{molec}}}\right)$$

and

$$\frac{N_2}{N_2 - N_1} \approx +\frac{kT_{\text{molec}}}{h\nu}.$$

The noise figure is referred to room temperature T_0,

$$P_{N0} \approx kT_0$$

and

$$F_{\min} = 1 + \frac{T_{\text{molec}}}{T_0}. \tag{25}$$

Thus noise figures of under 3 db can only be achieved by lowering the temperature of the molecular system: at dry ice temperatures, $T_{\text{molec}} = 194°\text{K}$, $F_{\min} = 2.3$ db, at liquid nitrogen temperatures, $T_{\text{molec}} = 77°\text{K}$, $F_{\min} = 1.1$ db, while at liquid helium temperatures $T_{\text{molec}} = 4°\text{K}$, $F_{\min} = 0.06$ db.

The desirability of both low temperatures and high densities points toward use of a solid molecular system. However, $\alpha \sim p^2$ argues for a gas, where electric dipole transitions with $p \sim 10^{-18}$ are available, and against a solid, where only paramagnetic resonance for which $p \sim 10^{-20}$ appears to provide sufficiently long relaxation times. Relaxation times in a gas of useful density are short, however, making the sweep technique of adiabatic fast passage very difficult to apply. Turning then to a solid (or liquid), the problem of finding a molecular system with a usably long relaxation time arises. Fortunately, systems are known with spin-lattice relaxation times of the order of many seconds.[23] These are systems of paramagnetic electrons localized on donor atoms in a silicon lattice. The donor atoms whose relaxation times have been measured include Group V elements (P, As, Sb) and lithium. The relaxation times vary with temperature and donor concentration, but for concentrations less than 10^{17}–10^{18} donors per cubic centimeter and at liquid helium temperatures, T_1 is of the order of a minute. Thus suitably doped silicon at liquid helium temperatures presents a high density, long relaxation time material suitable for making a low-noise amplifier[24] excited by adiabatic fast passage.

A possible amplifier using adiabatic fast passage excitation might consist of a doped-silicon sample in a microwave cavity in a helium cryostat located between the poles of an electromagnet. (See Fig. 11 opposite.) The time variation of the (dc) magnetic field H for such an amplifier is shown in Fig. 12. At point A, the sample is in thermal equilibrium with its surroundings in a magnetic field H_A. From A to B, the magnetic field is swept through H_R, which is the resonant field at the exciter microwave field frequency. This adiabatic fast passage inverts the spin state populations, leaving the sample in an emissive condition. From B to C, the field is kept constant at H_B, and the device acts as an amplifier of microwaves at the frequency

$$\nu = \gamma H_B = 2.8 H_B \text{ mc}.$$

At C, the field is abruptly returned to H_A, reaching H_A at D. Amplification at the frequency ν ceases, and the system is allowed to come to thermal equilibrium with its surroundings in the field H_A. Thermalized again at A', the cycle is repeated. This cycle produces a pulsed amplifier, with an amplification period from B to C and a dead-time, during which it is re-excited, from C to B'.

At first thought, it would seem that the dead-time C–B' would greatly exceed the active time B–C, since a time D–A' long compared to T_1 is required for the

[23] G. Feher and R. C. Fletcher, "Relaxation effects in donor spin resonance experiments in silicon," *Bull. Amer. Phys. Soc.*, vol. 1, p. 125; March 15, 1956 (Pittsburgh Meeting).

[24] J. Combrisson, A. Honig, and C. H. Townes, "Utilisation de la résonance de spins électroniques pour réaliser un oscillateur ou un amplificateur en hyperfréquences," *Compt. Rend.*, vol. 242, pp. 2451–2453; May 14, 1956.

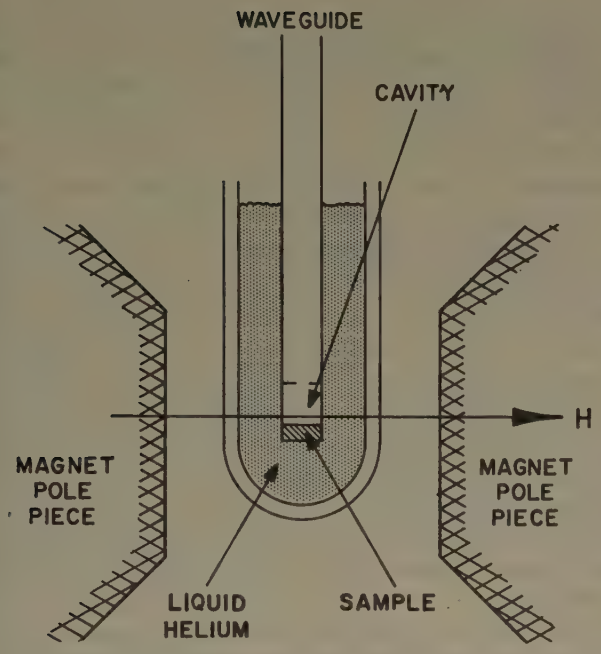


Fig. 11—Low-temperature paramagnetic amplifier.

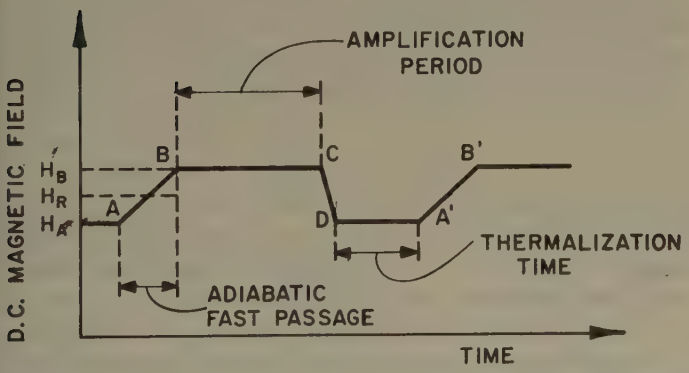


Fig. 12—Magnetic field vs time for a paramagnetic amplifier excited by adiabatic fast passage. H_B is the field during the amplification period, H_R the field at which the molecules are resonant at the exciter field frequency, and H_A the field at which thermalization occurs.

sample to reach thermal equilibrium. Fortunately, however, with a doped-silicon sample something can be done to shorten D–A' drastically. The long relaxation time (~1 minute) of this material at liquid helium temperatures is associated with the fact that the paramagnetic electrons are bound in the Coulomb-type potentials surrounding the donor atoms and that there are no free (conduction) electrons in the sample. If the sample (at liquid helium temperature) is illuminated with visible light, free carriers are released and T_1 is reduced to the order of a microsecond. A flash of light can thus shorten the required time for thermalization D–A' to a few microseconds. With an adiabatic sweep time A–B of a few milliseconds and an amplification time B–C of several seconds, it is seen that a nearly continuously amplifying device can be made. (It should be mentioned that by exciting the sample externally to the amplifier cavity, and providing a continuous "flow" of excited material through the amplifier, a truly steady state, or continuous amplifier can be obtained.)

The power available from the molecular system after excitation is given by

$$P_{\text{emission}} = \frac{4\pi^2 N p^2 \nu T_2 H_{rf}^2}{h},$$

where N is the excess number of spins in the upper state. The spectral line width is about

$$(\text{Bandwidth}) \approx \frac{1}{\pi T_2}.$$

Making the resistive losses in the cavity less than the emitted power by using high spin densities, using samples with sufficiently long T_2, and using a high-Q cavity, a high-gain cavity amplifier can be obtained.

The molecular bandwidth associated with the doped-silicon samples discussed above is several megacycles, indicating a T_2 of less than a microsecond. This is radically lower than $T_1 \approx 60$ seconds. The difference is caused by magnetic interactions between the paramagnetic spins, and between these spins and other magnetic dipoles in the sample (nuclear moments). These interactions dephase the electron spin-radiation field interaction, and hence broaden the resonance, but do not provide a means of exchanging energy with the crystalline lattice, and hence do not shorten T_1. By removing some of the dephasing nuclear moments and replacing them with nonmagnetic isotopes, T_2 can be increased and hence the molecular emission power increased, at, of course, a sacrifice of some amplification bandwidth.

The energy input in adiabatic fast passage comes from two sources: the high-level microwave exciter field, and (possibly) the energy associated with the magnetic moment of the system if the applied field is varied. With available cavity Q's, the losses from the exciter field are far greater than the microwave energy obtained in amplification, and so the efficiency of this system is low.

E. Multilevel Excitation Methods

The methods of achieving an emissive state discussed thus far have dealt with molecular systems where only two energy levels were significant.[25] There are other ways of obtaining an emissive state if one considers multilevel schemes and admits the possibility of one or more exciter frequencies different from the amplification frequency. Several possibilities for three-state systems

[25] In these two-level systems, other levels are of practical importance in determining the fraction of the total molecules in the system in the two levels of interest.

have been discussed by Basov and Prokhorov.[26] One basic approach with a three-state system can be seen by reference to Fig. 13. In one embodiment [Fig. 13(a)], the upper pair of states 2) and 3) are separated by the microwave frequency desired to be amplified, $\nu_{23}=\nu_{sig}$. Energy states 1 and 3 are also coupled by a radiation field, of frequency $\nu_{13}=\nu_{ex}$. At thermal equilibrium, there are more molecules N_{1eq} in state 1 than in either state 2, N_{2eq}, or state 3, N_{3eq}; in fact,

$$N_{1eq} > N_{2eq} > N_{3eq}.$$

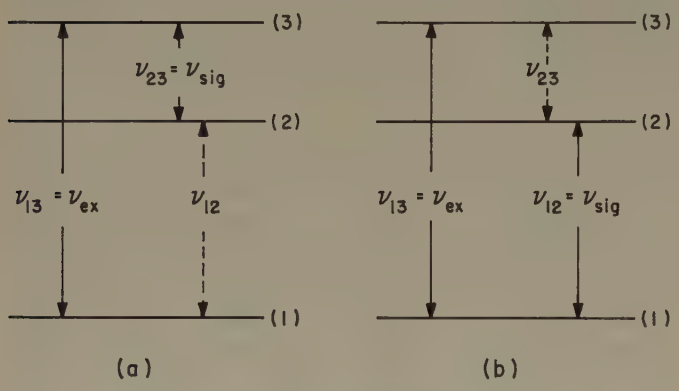


Fig. 13—Energy level diagram illustrating multilevel excitation methods.

If the resonance at $\nu_{ex}=\nu_{13}$ is saturated, however, this situation is altered. Here "saturated" means that the radiation field at frequency ν_{13} is so large that the effects of induced transitions completely override relaxation effects and the two states become equally populated. Saturating the transition at ν_{13} results in increasing the population N_3 of state 3. If this results in $N_3>N_2$, a steady state emissive condition is obtained. It must be noted that relaxation effects, despite the strong rf field at ν_{13}, may be very important in the final effective state populations attained. For example, if the relaxation mechanisms bringing the state populations N_3 and N_2 into thermal equilibrium are very weak, while those thermalizing N_1 and N_2 are strong, as state 1 is depopulated by the radiation, the relaxation mechanisms will transfer molecules from state 2 to state 1, in an attempt to maintain the equilibrium N_2/N_1 ratio. This will make the effective N_2 less than that corresponding to a condition of thermal equilibrium for the whole sample. It is clear that with a complicated system of levels and relaxation effects, many variations on this theme are possible. An obvious one is shown in Fig. 13(b): here the ν_{13} transition is again saturated, but a fast relaxation bebetween states 3 and 2 together with a weak relaxation mechanism between states 1 and 2 now makes $N_2>N_1$ and amplification occurs at a frequency $\nu_{sig}=\nu_{12}$.

[26] N. G. Basov and A. M. Prokhorov, "Possible methods of obtaining active molecules for a molecular oscillator," *J. Exper. Theoret. Phys. USSR*, vol. 28, pp. 249–250; February, 1955.

This general method of achieving an emissive molecular system can have the exceedingly desirable feature of combining the high molecular densities available in a solid with the continuous excitation of the gas devices discussed, by using a solid with appropriate energy levels and relaxation times. Some practical problems are posed by this excitation method, however. Since excitation is a continuous process, the same cavity must be used for both excitation and amplification. This means a cavity simultaneously operating in two modes, at two frequencies. Furthermore, the modes must be chosen so that, insofar as possible, regions of strong field for the excitation processes and regions of strong interaction for the amplification process coincide. This requirement cannot be met completely, of course, due to cavity mode orthogonality. However, with small sample sizes, this is a minor problem. If the amplifier operates at liquid helium temperatures, the heating effects of the saturating exciter field must also be considered. As in excitation by adiabatic fast passage, the presence of a strong exciter field with its relatively high losses makes multilevel excitation methods have low efficiency.

Multilevel methods of excitation open up another possibility of achieving low-noise amplification without resorting to low temperatures. Neglecting guide losses, the noise figure can be written (25),

$$F = 1 + \frac{T_{molec}}{T_0},$$

where T_{molec} is the "internal temperature" of the molecular system, defined by (2). With excitation methods that exchange, or invert, state populations, a $T_{molec}<T_0$ can only be achieved by physically cooling the molecular system (T_0 is *defined* to be room temperature). With the multilevel excitation scheme of Fig. 13, however, if the spin-lattice relaxation time T_{12} coupling states 1 and 2 is very much shorter than the relaxation time T_{23} coupling states 2 and 3, the internal temperature for the amplifier resonance between 2 and 3 is given by

$$T_{molec} = \left(\frac{\nu_{23}}{\nu_{12}}\right) \times (\text{Actual amplifier temperature}).$$

If ν_{23} is sufficiently below ν_{12}, the actual amplifier temperature can be room temperature and low-noise figures can still be obtained.

A major problem associated with this multilevel excitation method is in finding a suitable molecular system. The requirements are rather stringent: 1) the system must have three levels as shown in Fig. 13, with separations so that ν_{ex} occurs at a frequency where oscillators of reasonable power exist, and so that ν_{sig} is a desirable amplification frequency; 2), the selection rules must permit the transitions at ν_{13} and ν_{23} to be induced by radiation; 3), the relaxation time T_{13} must be long enough to permit saturation of the excitation resonance; 4), the relaxation time T_{23} must be considerably greater

than T_{12}; 5), molecular densitics must be high enough so that the molecularly emitted power exceeds the losses at the signal frequency. Requirement 4) can be expressed mathematically by

$$T_{23} > T_{12}\left(\frac{N_{2eq} - N_{3eq}}{N_{2eq} + N_{3eq}}\right)\left(\frac{N_{1eq} + N_{2eq}}{N_{1eq} - N_{2eq}}\right)$$

where N_{ieq} is the population of the ith level under conditions of thermal equilibrium (with no microwave fields present).

Fulfilling all five above requirements can only be done using very special systems. Such systems can be found in the energy level spectra of certain paramagnetic transition metals, using suitable compounds to achieve desired crystalline field splittings of otherwise degenerate energy levels. Work on an amplifier using multilevel excitation is being undertaken at Harvard University and elsewhere.[27]

F. Optical Pumping

Still another way to achieve an emissive state utilizing several energy levels is known as "optical pumping."[28] In "optical pumping," the system is illuminated with suitably polarized light of a wavelength corresponding to an optical transition of the molecules. The absorption of this *polarized* light, and subsequent spontaneous emission of *unpolarized* light can result in a rearrangement of molecules among a group of states so that those in two states connected by a microwave transition are in an emissive condition. To see this in more detail, consider an atom (molecule) with the (partial) energy level system shown in Fig. 14. There are two sets of energy levels of interest: the upper set consists of five degenerate levels and is separated from the lower set of three degenerate levels by an "optical transition" ($\nu = 10^{14}$ to 10^{15} sec^{-1}). The levels are designated by the quantum numbers F and M_F. F is the total angular momentum of the atom, in units of $h/2\pi$, about the Z axis, and M_F is the component of F along the Z axis.

Consider what happens to an atom that absorbs a photon from a beam of circularly polarized light traveling in the Z direction. Such a photon carries a Z component of angular momentum of one unit and one unit of total angular momentum. Assume the sense of polarization is such that the photon has an effective $M_z = +1$. Then the selection rule for absorption is $\Delta M_F = +1$, and an atom originally in the $F=1$, $M_F=-1$ state goes into the $F=2$, $M_F=0$ state upon photon absorption. Atoms in the upper set of levels are highly excited, however, and re-emit a photon spontaneously in about 10^{-8} seconds. This photon is generally unpolarized, as the selection rule for spontaneous emission is $\Delta M_F = \pm 1$ or 0. This is indicated for the $F=2$, $M_F=0$ state on Fig. 14. It is seen that after a complete cycle of absorption and re-emission, an atom originally in the $F=1, M_F=-1$ state can be in any of the three $F=1$ states. An atom that was initially in the $F=1$, $M_F=+1$ state, however, must remain in the same state after a cycle, as the only transition possible in reemission is the $\Delta M_F = -1$ one.

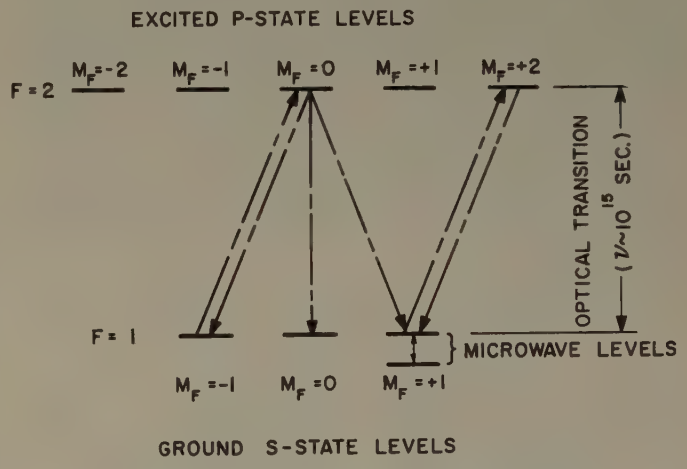


Fig. 14—Schematic energy level diagram showing optical transitions as used in "optical pumping." M_F is the component of total angular momentum F along the axis of the system.

It can therefore be seen that illumination of the system with polarized light can result in an effective depopulation of some levels ($F=1$, $M_F=-1$ in the case above) and an increase in population of others ($F=1$, $M_F=+1$ above). If a state that is increased in population is also coupled by a microwave transition to a lower state (as shown in Fig. 14), an emissive condition may be maintained with respect to these two levels. Such a gas of atoms could be used in a suitable microwave structure as an amplifying or oscillating medium.

There are several practical difficulties besetting the utilization of this method for obtaining a molecular system in an emissive condition. First, a molecule or atom having a suitable energy level scheme must be found. The alkalai metal vapors and atomic hydrogen fulfill this requirement; the optical transition is between the $^2S_{1/2}$ atomic ground state of the atoms and the first excited P state, while the hyperfine structure of the ground state provides the microwave transition. Vapor pressures, which determine available gas densities, and, in the case of atomic hydrogen, recombination processes, must also be considered. If the optical transition is in either the near infrared or the ultraviolet, polarization difficulties may arise.

[27] N. Bloembergen, "Proposal for a new type solid state Maser," *Phys. Rev.*, vol. 104, pp. 324–327; October 15, 1956.
H. E. D. Scovil, C. Feher, and H. Seidel, "The operation of a solid state maser," (to be published).

[28] A Kastler, "Quelques suggestions concernent la production optique et la détection optique d'une inégalité de population des niveaux de quantification spatiale des atoms," *J. Phys. Rad.*, vol. 11, pp. 255–265; June, 1950.
J. Brossel, A. Kastler, and J. Winter, "Création optique d'une inégalité de population entre les sous-niveaux zeeman de l'état fondamental des atoms," *J. Phys. Rad.* vol. 13, p. 668; December, 1952.
W. B. Hawkins and R. H. Dicke, "The polarization of sodium atoms," *Phys. Rev.*, vol. 91, pp. 1008–1009; August 15, 1953.

In the above description of the "optical pumping" process, several simplifying assumptions were made. One was that the absorption process could be considered to go between an initial state and *one* final state. The upper optical levels are very broad, however, and the possibility exists of two such states, to both of which the selection rules permit transitions, "overlapping." In this case, complex "interference" effects occur; their result is that the excited atom "remembers" the angular momentum absorbed and tends to reemit it again, thus leaving no net "pumping" effect. It was further implicitly assumed that only one of the two microwave-coupled levels was optically coupled to the upper optical levels. Because optical lines are so broad, this cannot be achieved, and the populations of both of the microwave levels may be altered by "optical pumping." It can be shown, however, that in favorable cases both these possible sources of difficulty do not prevent an emissive state from being attained.

A sketch of one practical way in which an "optically pumped" amplifier might be achieved is shown in Fig. 15. The molecular system consists of rubidium vapor at

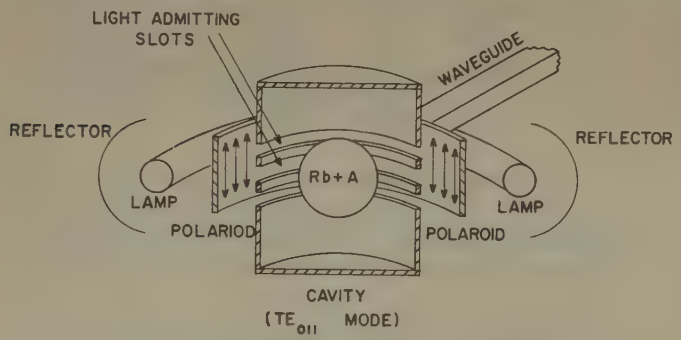


Fig. 15—"Optically pumped" amplifier.

a pressure of roughly 10^{-6} mm Hg. The microwave transition is between the hyperfine levels of the ground state, and occurs at 6834.68 mc. The optical transition is in the near infrared at about 7900 *A*. This can easily be linearly polarized using Polaroid sheets. The rubidium vapor is contained in a small glass bulb at the center of the microwave cavity. Argon at a pressure of about one mm Hg is also in the bulb. This increases the diffusion time of the rubidium vapor to the walls of the bulb, and effectively eliminates Doppler effects.[29] The cavity is cylindrical and resonant in the TE_{011} mode. The light, polarized along the cavity axis, is incident on the vapor through circular slots cut in the walls of the cavity. This can be done without greatly affecting the Q of the desired resonant mode. The effect of "optical pumping" on the population of the various hyperfine energy levels is shown in Fig. 16. At thermal equilibrium, the states are populated as shown on the upper series of energy levels. After each atom has absorbed and re-emitted an optical photon, the distribution is as shown on the lower series of levels. It is clear that for the three $\Delta M_F = 0$ transitions, the system after "pumping" is highly emissive, and in fact corresponds to the very low negative internal temperature $T_{molec} = 0.12°K$.

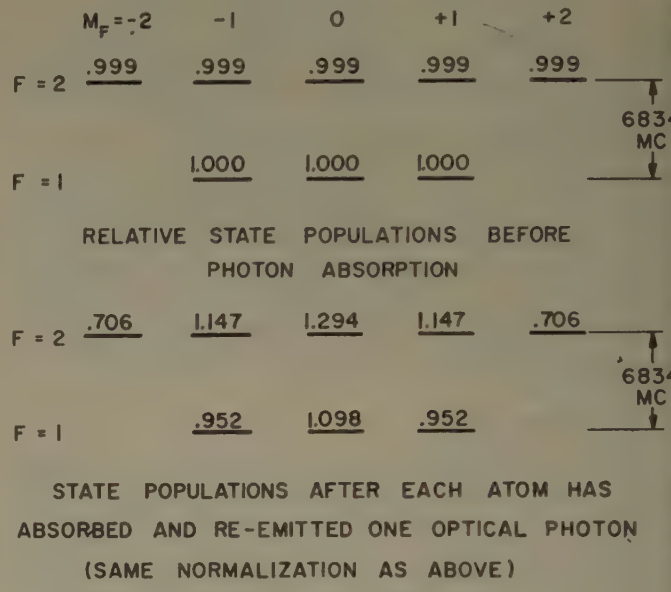


Fig. 16—Effect of "optical pumping" on the state populations of the magnetic substates of the hyperfine levels of the ground S state of rubidium vapor. F is the total angular momentum of an atom and M_F its component along the axis of the system.

The major weakness of amplifiers based on this excitation method is a quantitative one. It seems necessary to go to a gaseous system to find a molecular energy level scheme that is suitable. Furthermore, the density of the active gas must be relatively low, as indicated above, or "light trapping" occurs; that is, the optical photon re-emitted by one excited atom is reabsorbed by another before it can "escape" from the gas. Since the re-emitted photon is unpolarized, its reabsorption tends to "unpump" the atom absorbing it. Thus the total "excess population" N is very low. Also, at least in the molecular systems listed above, the microwave transition is a *magnetic* dipole one, with the accompanying low dipole moment p.

Because of these factors, to get amplification it is necessary to make the bandwidth extremely small. For this reason, optically pumped amplifiers may be limited to applications where this is an advantage: high spectral purity oscillators and frequency standards. A frequency standard, or "atomic clock" using optically pumped rubidium vapor is under study at Princeton University.[30] The expected molecular bandwidth of this rubidium amplifier, with its utilization of a "buffer gas" to eliminate Doppler effects, is of the order of 100 cps. Since the

[29] R. H. Dicke, "The effect of collisions upon the Doppler width of spectral lines," *Phys. Rev.*, vol. 89, pp. 472–473; January 15, 1953.

[30] I am indebted to Dr. T. R. Carver of Princeton University for permission to quote the results of calculations on this device that he has made. The numerical example given in the text is based on his work.

amplification bandwidth, or noise-induced frequency modulation as an oscillator should be much less than this, a very high frequency stability should be achieved.

The calculation of an "oscillator parameter L" (see Section III, C) for this device is difficult, as several unknown factors enter. However, an estimate indicates that a loaded cavity Q of about 60,000 is required to sustain oscillations (*i.e.*, for $L=1$). With the glass bulb in the cavity and the slots for the admission of the polarized light, this may be an unattainable Q. Even if it ultimately so proves, however, such a device will provide an extremely sharp resonance that can be used for frequency control purposes.

The efficiency of an optically-pumped amplifier is very low. Nearly all of the (relatively) huge amount of energy supplied in the optical frequency range is lost, either in optical reradiation or in resistive losses to heat in the cavity.

V. Discussion

The above perhaps gives some idea of the wide variety of devices and systems covered by the common title of "molecular amplifier." While it is believed that the most promising amplifier schemes now proposed or being worked on have been included in this discussion, it is also quite certain that this listing is not a final, definitive one. The wide range of approaches to emissive states indicated have all been invented or developed within the past few years, and it seems highly unlikely that the field is already exhausted of novel solutions to its problems.

This diversity has in some respects prelcuded a general discussion of molecular amplifiers and oscillators, and necessitated separate descriptions for each of the excitation methods and molecular systems. The basic properties of all molecular amplifiers are quite similar however. The weakness of the individual molecular interactions in the microwave region, of the order of 10^{-5} to 10^{-4} electron volts per molecule, argues strongly for the use of a resonant microwave structure for the region of interaction between molecules and radiation. With such a structure, which includes built-in positive feedback, gain is of itself no problem: by increasing feedback, *i.e.*, cavity Q, any desired gain can be obtained. The problem of power losses in the microwave structure, on the other hand, is a real one. Extremely loss-free structures are needed so that the weak molecular power exceeds losses by a sufficient margin to permit low-noise operation.

There are two main sources of noise in a molecular amplifier: noise due to spontaneous incoherent emission from the excited molecules, and noise from emission induced by thermal radiation from the microwave structure.[31] The latter can often be reduced by cooling the microwave structure. Despite these noise sources, noise figures of under 1 db can be achieved, and in many communications and radar systems where the signal source is such that the background noise entering the amplifier is well below thermal noise at room temperature, this indicates a tremendous increase in sensitivity over conventional microwave amplifiers with noise figures in the range 5–15 db.

Low-noise figure is directly related to the spectral purity when the amplifier is operated as an oscillator. It was seen that the heretofore unattainable short-term frequency stability of a few parts in 10^{12} can be achieved with the molecular beam Maser, thus opening up new possibilities for the design of super-stable frequency standards based on atomic processes. These provide a standard of frequency at any place on the earth independent of astronomical observations, radio-transmitted standard frequency signals, etc.

The power handling capabilities of molecular amplifiers have been seen to be low. In some applications, this is a definite disadvantage; for example, in military radar such an amplifier could easily be saturated by a jamming signal. In other applications, however, the low power handling ability of molecular amplifiers provides no serious limitation to their use.

A major problem of molecular amplification, in addition to that of reduction of losses in the microwave structure, is that of bandwidth, or, more exactly gain-bandwidth. As seen above, gain can always be traded for bandwidth, by using an inhomogeneous Stark or Zeeman field to broaden the resonance, by increasing molecular density and hence shortening relaxation times, or by increasing the microwave coupling to the interaction cavity. However, when the molecular emission power is spread over a broad bandwidth, the gain and noise figure worsen. Achievement of a high total available molecular power therefore is of great importance. For gaseous molecular systems, molecular densities are low and bandwidths of a few kilocycles to a few tens of kilocycles are available. With solid-state devices, bandwidths of megacycles should be obtainable.

In addition to gain, noise figure, and bandwidth, frequency coverage is of importance. If the amplification frequency is determined by internal molecular properties, such as in ammonia and possibly in some solid state systems, the frequency is essentially fixed. In some applications, such as a frequency standard, this is desirable, or at least not objectionable. In case a tunable amplification frequency is required, a system such as a paramagnetic spin system where the frequency is determined by the strength of an applied static field can be used. An important possibility arises in this case. Since the excitation frequency is not necessarily the amplification frequency, it is possible to generate microwaves at frequencies higher than those of excitation. This is a possible approach to the problem of the generation (or amplification) of millimeter waves. Methods such as

[31] Additional noise is introduced when the number of interacting molecules fluctuates in time. This is generally relatively unimportant.

the molecular beam Maser that do not utilize rf electromagnetic excitation also offer a possibility for the generation of discrete frequencies in the millimeter and submillimeter region, by using transitions between relatively widely separated energy states. Vibrational transitions and certain rotational transitions, as, *e.g.*, in ammonia, lie in the far infrared and submillimeter part of the frequency spectrum and might prove suitable.

Thus molecular amplifiers provide a means of achieving low noise amplification of microwaves. At present, bandwidths are quite low, but developments in the near future should greatly improve this situation. Below microwave frequencies, the gain fall-off with frequency will probably preclude their use; in the millimeter and submillimeter range, they offer new possibilities for amplification and generation. Many developments both in excitation methods and in molecular systems suitable for use in these devices can be expected in the near future.

Appendix

Consider a molecule with two energy levels, with an oscillating microwave field $E \cos (2\pi\nu t)$ inducing transitions between them. If the state function of the molecule is written as a linear combination of pure energy state functions, as in (1),

$$\psi = \sum_j a_j(t)\psi_j, \tag{1}$$

then the quantum mechanical equations for the time dependence of the a_j's are given by:[32]

$$\frac{da_j}{dt} = \frac{2\pi}{ih} \sum_n W_{jn} a_n \exp (2\pi i \nu_{jn} t). \tag{26}$$

Here $i = \sqrt{-1}$, $\nu_{jn} = (W_j - W_n)/h$, W_j is the energy of the jth state, etc., and W_{jn}, the jnth element of the perturbation matrix, is given by

$$\begin{aligned} W_{jn} &\equiv \int \psi_j^* W \psi_n dv \\ &= \int \psi_j^* (pE \cos (2\pi\nu t)\psi_n dv \\ &= E \cos (2\pi\nu t) \int \psi_j^* p \psi_n dv. \end{aligned} \tag{27}$$

The integral represents p_{jn}, the strength of the dipole moment coupling the states j and n.

In the two-state problem at hand, (26) and (27) become

$$\frac{da_1}{dt} = \frac{2\pi E \cos (2\pi\nu t)}{ih} [p_{11}a_1 + p_{12}a_2 \exp (2\pi i \nu_{12} t)]$$

$$\frac{da_2}{dt} = \frac{2\pi E \cos (2\pi\nu t)}{ih} [p_{21}a_1 \exp (2\pi i \nu_{21} t) + p_{22}a_2].$$

[32] L. I. Schiff, "Quantum Mechanics," McGraw-Hill Book Co., Inc., New York, N. Y., pp. 189–190; 1949.

Here p_{ii} indicates the dipole moment possessed by a molecule when it is in the state of energy W_i. Such static dipoles do not lead to resonant transition effects and will be neglected; also $p_{12} = p_{21} = p$, in the cases of interest at present, so

$$\frac{da_1}{dt} \approx \frac{2\pi pE}{ih} \cos (2\pi\nu t) \exp (2\pi i \nu_{12} t) a_2$$

$$\frac{da_2}{dt} \approx \frac{2\pi pE}{ih} \cos (2\pi\nu t) \exp (2\pi i \nu_{21} t) a_1.$$

Also, $\nu_{21} = -\nu_{12} = \nu_0$, and defining $\nu \equiv \nu - \nu_0$,

$$\frac{da_1}{dt} = \frac{\pi pE}{ih} \{\exp [2\pi i \Delta\nu t] + \exp [-2\pi i(\nu + \nu_0)t]\} a_2$$

$$\frac{da_2}{dt} = \frac{\pi pE}{ih} \{\exp [2\pi i(\nu + \nu_0)t] + \exp [-2\pi i \Delta\nu t]\} a_1.$$

The terms with $(\nu + \nu_0)$ represent very high frequency perturbations on the basic behavior of the system. As they do not lead to any net transition effects over a reasonable averaging time, they can also be neglected, leading to

$$\frac{da_1}{dt} = \frac{\pi pE}{ih} \exp (2\pi i \Delta\nu t) a_2$$

$$\frac{da_2}{dt} = \frac{\pi pE}{ih} \exp (-2\pi i \Delta\nu t) a_1. \tag{28}$$

It can be readily shown that the expressions

$$a_1 = \exp (\pi i \Delta\nu t) \left[\cos \lambda t - \frac{\pi i \Delta\nu}{\lambda} \sin \lambda t\right]$$

$$a_2 = \frac{\pi ipE}{h\lambda} \exp (-\pi i \Delta\nu t) \sin \lambda t$$

satisfy (28) if

$$\lambda = \pi \left[(\Delta\nu)^2 + \left(\frac{pE}{h}\right)^2\right]^{1/2}.$$

Furthermore, at $t = 0$ they reduce to

$$a_1(0) = 1$$
$$a_2(0) = 0.$$

For such a molecule in energy state 1 at time $t = 0$, the probability that it has undergone a transition and is in state 2 at time t is:

$$\text{Transition probability} = |a_2(t)|^2$$
$$= \frac{\left(\frac{pE}{h}\right)^2 \sin^2 \left\{\pi \left[(\Delta\nu)^2 + \left(\frac{pE}{h}\right)^2\right]^{1/2} t\right\}}{(\Delta\nu)^2 + \left(\frac{pE}{h}\right)^2},$$

which is (6) in the text.

The Spacistor, A New Class of High-Frequency Semiconductor Devices*

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Summary—**New devices are considered in which electrons or holes are injected directly into space-charge regions of reverse-biased junctions avoiding the diffusion of carriers through field-free regions. The case considered is one in which the junction is biased at a voltage such that the injected carriers are multiplied by the avalanche process. A device of this type shall be called a spacistor. It is shown that negative resistance devices and amplifying devices may be constructed. The difficulty is the accumulation of the generated carriers in front of the emitting contact. Experimentally, it has been found that this accumulation of carriers results in the spontaneous relaxation-type oscillations of a transistor-like structure operated at collector voltages greater than the punch-through voltage. It is suggested that the accumulation effect may be diminished by the use of small emitters and magnetic fields.**

Introduction

THE FREQUENCY range of transistors has been extended considerably in the past few years.[1–6] An investigation was made to determine types of oscillating or amplifying semiconductor devices which are, in principle, capable of extending the useful frequency range of transistors to even higher frequencies. In addition to extrinsic base resistance and the collector capacity, the α-cutoff frequency essentially limits the frequency response of a transistor. The α-cutoff frequency can be considered to arise from the finite "transit time" of a minority carrier through the base region and the collector space-charge region. The base region of the transistor is either field free or has a relatively weak built-in field with a potential drop of 0.1 to 0.2 volts. Thus the "transit time" in present transistors has been determined almost completely by the characteristics of the base region. Therefore new devices were constructed which no longer use the diffusion of minority carriers through virtually field-free regions.

The first attempt in this direction has been made by Shockley[7] with the so-called unipolar field-effect transistor. It appears, however, that this device will not exceed the frequency response of the transistor.[8] Another approach to the same problem made by Shockley[9] used the transit time through the space-charge regions of reverse-biased junctions to obtain negative resistance in a small frequency interval. This problem has recently been reconsidered by Read[10] who proposes to obtain negative resistance by the use of the transit time through space-charge regions in conjunction with the build-up time of avalanche breakdown. The latter approaches[9,10] may result in useful oscillators at a frequency which is of the order of the inverse transit time of a carrier through the space-charge region of a junction and may, thus, be of the order of 10^4 mc.

In the present paper, new devices are suggested which also use processes in space-charge regions of reverse-biased junctions. However, in all the devices proposed here, a third injecting contact is made to the space-charge region. Only devices will be considered for which the junction is biased with a voltage high enough so that avalanche multiplication takes place to an appreciable extent. A device using these principles shall be called a spacistor. Two possible geometrical arrangements will be discussed in detail. In the first, an injecting "point" contact is made into the space-charge region of a reverse biased p-n junction. In the second, a transistor-like structure is discussed. The base region has a width such that the collector space charge extends to the emitter junction or "punches-through" at a voltage which is near the avalanche breakdown voltage.

It has not yet been possible to construct the former device successfully; however, extensive experimental studies have been made of the latter structure. From these studies it became apparent that there is a tendency for carriers generated by the avalanche multiplication mechanism to accumulate in front of the injecting emitter and, thus, greatly alter the space charge there. This accumulation results in relaxation-type oscillations when the injecting contact is biased with a high resistance source. It may be possible that use of a small emitter in conjunction with a magnetic field in the base will eliminate the carrier accumulation and thus prevent the undesired oscillations.

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[10] W. T. Read, Jr., "A Proposed High-Frequency, Negative Resistance Diode Using Breakdown and Transit Time," Paper given at AIEE-IRE Semiconductor Devices Res. Conf., Purdue Univ., Lafayette, Ind.; June, 1956.

A Negative Resistance Device

A p-n junction with an applied reverse bias is shown in Fig. 1(a). The p-type region is considered to be doped the more heavily of the two so that the space charge extends mainly into the n-type region. If the doping in the n- and p-type region is uniform, then a plot of the potential is distributed parabolically as a function of distance on either side of the junction. In Fig. 1(b), the potential distribution in the space-charge region is shown for two applied voltages V_1 and V_2. Next, consider a small p-type contact situated in the space-charge region as shown in Fig. 1(a). This contact will be referred to as a "bond."

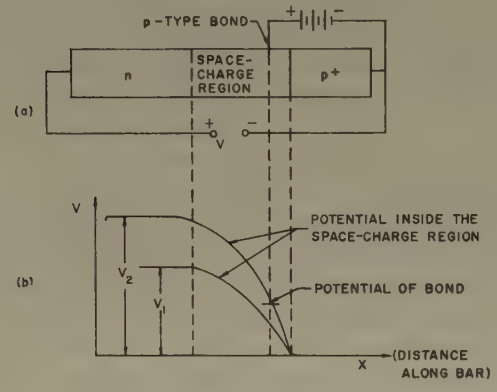


Fig. 1—(a) Negative resistance device, and (b) potential distribution in space charge of junction.

If this bond is electrically open-circuited, then it will essentially assume the potential that exists in the space-charge region immediately under it. However, if the small bond region is biased positively with respect to the potential in the underlying space-charge region, holes will be emitted into this region. Since the geometry of the device is not one-dimensional, a calculation cannot be carried out readily; however, it is expected that the emission of holes is "space-charge limited" and qualitatively similar to the one-dimensional case.[11] If the small p-type bond is biased negatively with respect to the potential of the underlying space charge, no emission of holes will take place. Some holes which are generated thermally in the n-type region within a diffusion length of the junction and which flow through the space-charge region will be collected by the small bond.

Suppose that the p-type bond is connected in series with a battery to the p-region as indicated in Fig. 1(a). The voltage of the battery is chosen such that the bond has a potential as indicated in Fig. 1(b). For the lower applied voltage V_1, the bond emits holes into the space-charge region; for the higher applied voltage V_2, no holes are emitted. In the following discussion only the emitted current will be considered. A sketch of the dependence of emitted bond current on applied voltage V is shown in Fig. 2(a). Applied voltages which are less than the bond bias voltage are not of interest here. This voltage region is marked by a shaded area in Fig. 2. In this case, holes will not only flow to the p-side but will also be emitted into the n-region. In the n-region there is virtually no field and the holes will diffuse and recombine. This diffusion process is a relatively slow one. However, consider the situation when the applied voltage exceeds the bond bias. Obviously, with no avalanche multiplication, the emitted hole current will not cause any additional current to flow through the terminals across which V is applied. A current can be induced in this circuit only if the emitted holes create electron-hole pairs at the junction. The electron-hole pairs are separated by the field of the junction, and a current flows. The magnitude of this current is

$$I = (m - 1)I_{\text{Bond}}, \tag{1}$$

where m is the avalanche multiplication factor and I_{Bond} is the current emitted by the bond. The multiplication factor is not necessarily the same as in the isolated junction since the bond distorts the field. The electric field in the vicinity of the junction will depend, to an appreciable degree, on the voltage applied to the bond which, of course, is independent of the applied voltage V. Therefore, the variations of m with applied voltage are expected to be smaller when the bond is biased than when it is not. Thus, the diode current characteristic will be as indicated in Fig. 2(b); there may be a maximum in the I, V curve as indicated by the dashed line. It is, however, difficult to predict the exact shape of the curve without a detailed calculation.

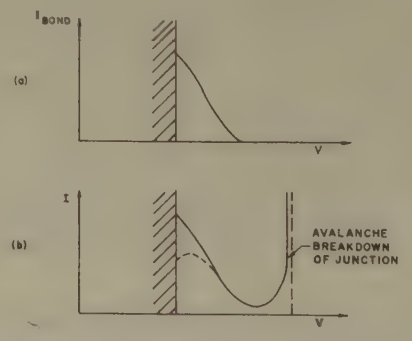


Fig. 2—(a) Bond current as a function of applied voltage V. (b) Diode current as a function of applied voltage V.

It can be stated, quite generally, that there must be a negative resistance region because the current emitted by the bond becomes zero at a certain voltage; and thus, the induced current also becomes zero. The small current still flowing at the minimum of the I, V curve is the multiplied saturation current of the junction. If the applied voltage is increased to even higher values, the junction eventually breaks down. Devices with negative resistance regions may be used as high-frequency oscillators. Also, bistable devices for high speed switching can be built.

[11] W. Shockley and R. C. Prim, "Space-charge limited emission in semiconductors," *Phys. Rev.*, vol. 90, pp. 753–758; June, 1953.
G. C. Dacey, "Space-charge limited hole current in germanium," *Phys. Rev.*, vol. 90, pp. 759–763; June, 1953.

Consider the size of a typical space-charge region. Suppose the avalanche-breakdown voltage occurs at 200 volts. This implies, for example, in germanium[12] that the n-type side contains about 6×10^{14} donor atoms per cm^3. The width of the space-charge region is

$$W = \sqrt{\frac{2\epsilon}{\rho}V}, \tag{2}$$

where V is the applied voltage, ϵ is the dielectric constant of the semiconductor, and ρ is the charge density due to the ionized donors. For V equal to 200 volts, this width becomes, for the above mentioned concentration of donors, $W=2.4\times10^{-3}$ cm. For V equal to 100 volts, the width will be about 1.7×10^{-3} cm. The problem of making bond contacts much smaller than the above widths has not been solved. In experiments performed at this laboratory with unformed tungsten points placed into the space-charge region no emission of holes was observed. The emission of holes from a point contact depends upon the formation of an inversion layer under the point contact. To ensure hole emission it therefore seems desirable to create a small p-type region by doping.

There are, however, many ways by which the above described task can be simplified. For example, nonconstant doping may be used (see Fig. 3). On the left of the

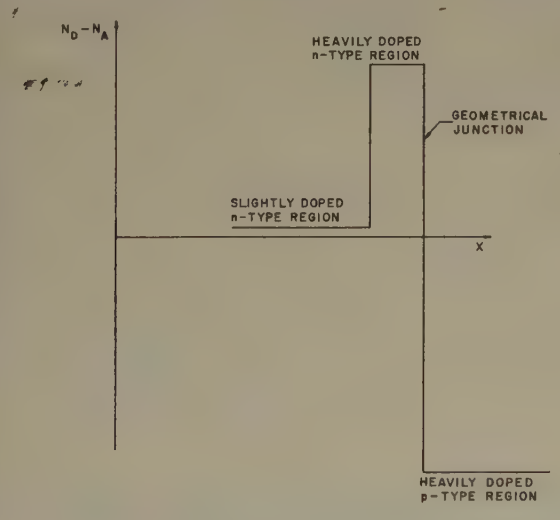


Fig. 3—Scheme of donor minus acceptor concentration for a proposed negative resistance device.

junction there is a heavily doped n-type region followed by a slightly doped n-type region. One may choose the width and impurity concentration of the heavily doped region such that the space charge includes this region for an applied voltage at which appreciable multiplication takes place. A relatively small increase in applied voltage will then cause a rapid increase in the space-charge width because of the adjacent nearly intrinsic region, without affecting the multiplication factor appreciably. By a scheme like this, the space-charge region can be made relatively wide, and at the same time, multiplication will occur at relatively low applied voltages.

Devices With Transistor-Like Structures

As an example of another structure, consider a regular alloyed-junction transistor with a relatively small base width. The base width is assumed to be of such a magnitude that punch-through takes place at a collector voltage which is an appreciable fraction of the avalanche-breakdown voltage. In this transistor, the collector corresponds to the p^+-side of the diode of Fig. 1(a), the emitter corresponds to the p-type bond, and the base region corresponds to the n-side of the diode. Because of the plane parallel geometry of emitter and collector junction, significant differences exist between the two devices.

First, consider the floating potential of the emitter junction as a function of the voltage applied between the base region and the collector.[13] Before punch-through, the emitter is slightly reverse biased, and the voltage difference is given by[14,15]

$$V_f = -\frac{kT}{q}\ln(1-\alpha),$$

where k is Boltzmann's constant; T, the absolute temperature; q, the electronic charge; and α, the emitter to collector current amplification factor. This floating potential rarely exceeds 0.1 to 0.2 volt. However, after punch-through has taken place, the voltage difference between emitter and collector remains constant as the collector junction bias is varied. This can be seen schematically in Fig. 4. In Fig. 4(b) three cases are shown. In the first case, the applied voltage V_{BC} is less than the punch-through voltage V_P; the space charge does not extend to the emitter. In the second case, $V_{BC}=V_P$ and the space charge extends up to the emitter junction. In the third case, $V_{BC}>V_P$; the solution of Poisson's equation is the same for this case as for $V_{BC}=V_P$ except for an additive constant in the potential. The reason is that the electric field must vanish in front of the emitter junction just as it does for $V_{BC}=V_P$. Thus, $V_{BC}-V_{BE}=V_P$, where V_{BE} is the potential difference between base and emitter [see Fig. 4(b)].

If a voltage is applied between emitter and collector which is somewhat larger than the punch-through voltage, a current will flow. This current is independent of the voltage V_{BC} as long as $V_{BC}>V_P$. Results on a typical experimental unit when V_P is equal to 12 volts are

[12] S. L. Miller, "Avalanche breakdown in germanium," *Phys. Rev.*, vol. 99, pp. 1234–1241; August, 1955.

[13] H. Schenkel and H. Statz, "Voltage punch-through and avalanche breakdown and their effect on the maximum operating voltages for junction transistors," *Proc. Nat. Elect. Conf.*, vol. 10, pp. 614–625; 1954.

[14] W. Shockley, "The theory of P-N junctions in semiconductors and P-N junction transistors," *Bell Syst. Tech. J.*, vol. 28, pp. 435–489; July, 1949.

[15] W. Shockley, M. Sparks, and G. K. Teal, "P-N junction transistors," *Phys. Rev.*, vol. 83, pp. 151–162; July, 1951.

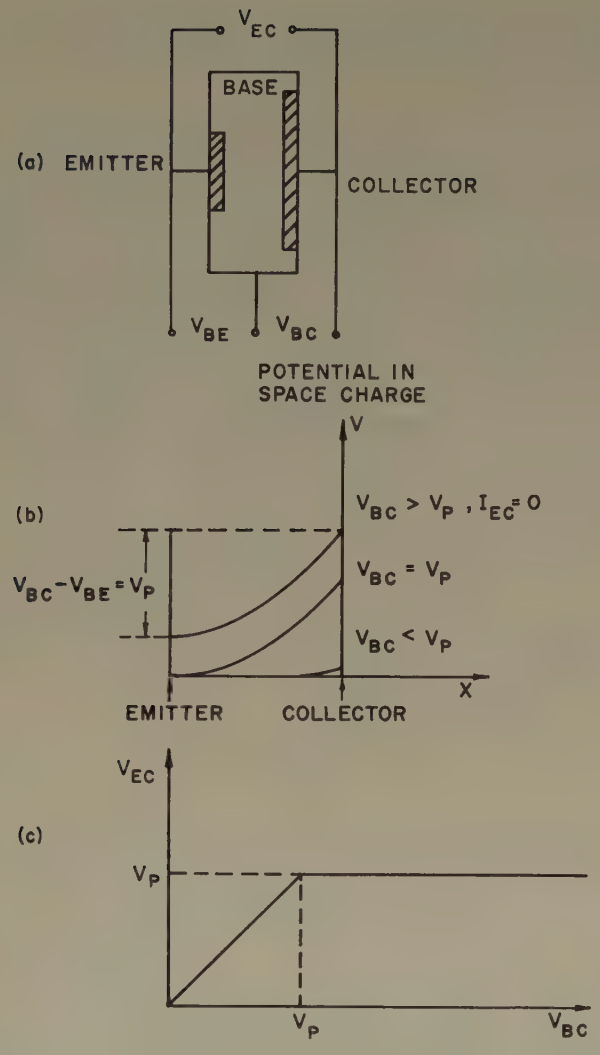


Fig. 4—(a) Cross section of transistor-like structure. (b) Potential distribution in base for three voltages V_{BC}. (c) Open circuit voltage between emitter and collector as a function of voltage between base and collector.

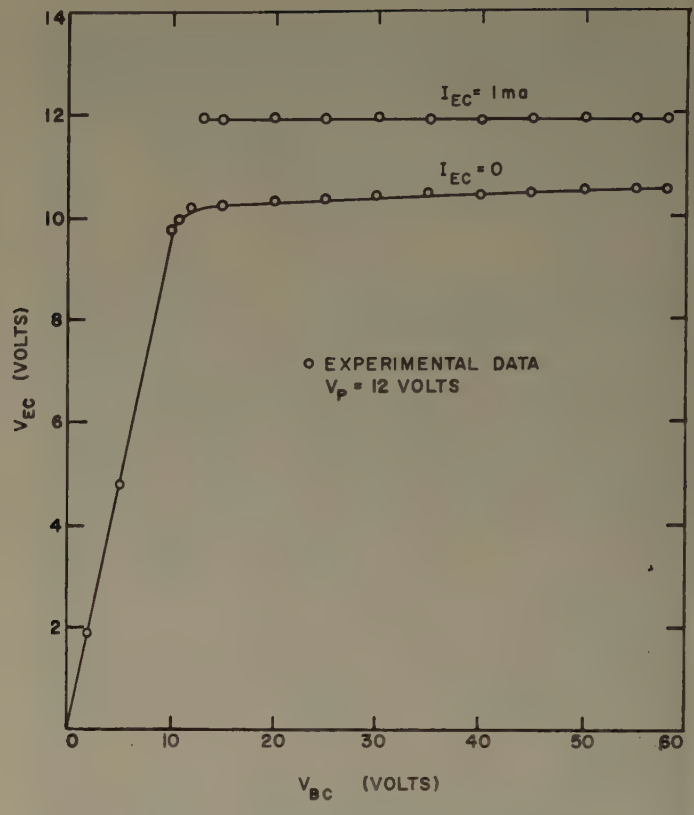


Fig. 5—Emitter to collector voltage as a function of base to collector voltage for $I_{EC}=0$ and $I_{EC}=1$ ma.

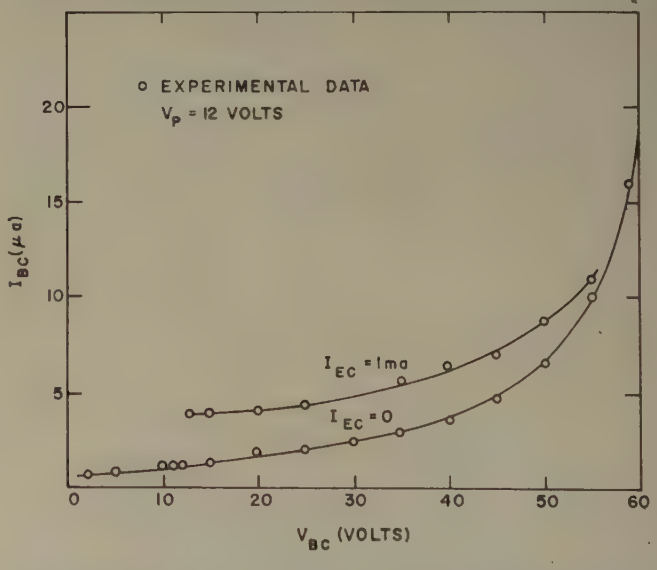


Fig. 6—Base current as a function of base to collector voltage for $I_{EC}=0$ and $I_{EC}=1$ ma (punch-through voltage approximately 12 volts).

shown in Fig. 5. When I_{EC}, the current flowing from emitter to collector is zero, the voltage V_{EC} varies slightly with V_{BC}; however, when I_{EC} equals 1 ma, V_{EC} is practically independent of V_{BC} provided the latter exceeds the punch-through voltage. The input resistance dV_{EC}/dI_{EC} is a function of the current I_{EC}. This resistance decreases with increasing current. If multiplication takes place near the collector junction, electron-hole pairs will be generated. The electrons should not flow into the emitter but should rather flow out into the base; and thus, a current I_{BC} may be induced in the high resistance collector circuit. If the ratio of the output resistance to the input resistance is high enough, and if the avalanche multiplication factor is large enough, then it should be possible to obtain power amplification. In Fig. 6, the base current I_{BC} is shown as a function of collector voltage for I_{EC} equal to zero and 1 ma (for the transistor as of Fig. 5). It may be seen that some leakage current flows across the collector junction. As expected, the current in the base-collector circuit is somewhat higher for $I_{EC}=1$ ma. However, in this case, the multiplication is very small. From these curves, a value of approximately 0.0026 is obtained for $(m-1)$. From the constant difference between the collector currents it is seen that $(m-1)$ is essentially independent of collector voltage for $V_{BC}>V_P$. (At high values of V_{BC}, heat generated in the collector causes deviations.) The factor m is nearly constant because the field distribution between emitter and collector is essentially independent of the voltage applied between base and collector when $V_{BC}>V_P$.

The disadvantages of the transistor-like geometry become quite apparent when units having considerably higher multiplication factors than the above are investigated, *i.e.*, transistors in which the punch-through voltage V_P is a larger fraction of the avalanche-breakdown voltage V_A. In all the transistors investigated, for which the ratio V_P/V_A was approximately 0.5 or greater, spontaneous oscillations have been observed. A typical circuit in which these oscillations occur is shown in Fig. 7. The spontaneous oscillations are due to the fact that there is essentially no transverse field along the surface of the emitter so that in a *p-n-p* type structure the generated electrons tend to accumulate in front of the emitter.

In Fig. 8, the emitter-collector voltage V_{EC} and the base current I_{BC} are shown as a function of time; departures from these sketches attributable, probably, to ringing in the circuit, have been omitted. The curves suggest a relaxation type of oscillation which can be explained as follows: There is always some stray capacity in the external circuit between emitter and collector, and the device itself has some internal capacity. If initially $V_{EC}=0$, *i.e.*, there is no voltage difference between emitter and collector, the battery in Fig. 7 proceeds to charge this capacity. Experiments show that the charge time can be explained if the device is assumed to be nonconducting during this time interval. Letting C represent the total capacity, the charge time T is equal to CV_P/I, if a constant current source I is used, as shown in Fig. 8. When the capacity has charged to a value $V_{EC}\approx V_P$, the device becomes conducting, and completely discharges the capacity, that is, V_{EC} decays to essentially a zero value. The interval of discharge T_d was so short that it could not be measured with accuracy with the available equipment, when C was the residual stray capacity ($\approx$20 $\mu\mu$f). (T_d is the time in which V_{EC} decays from 0.9 to 0.1 of its initial value.) This time is estimated to be of the order of a few millimicroseconds for the transistors investigated. The transistors used were of the CK762-type having cutoff frequencies between 14 and 25 mc at a collector bias of 6 volts.

It is interesting to observe that the base current is delayed relative to the discharge and it flows for a much longer period of time compared to the discharge time T_d. It can be shown that the maximum repetition rate is related to the time it takes for the accumulated electrons to leave the base region. Repetition rates of 50 mc have been observed.

The energy bands along a line connecting the emitter and collector appear in Fig. 9 (next page). There is a potential maximum just in front of the emitter which limits the flow of holes from the emitter region.[11] If the emitter supply voltage between emitter and collector is made slightly greater than V_P, holes will flow from emitter to collector. At the collector, each hole will create on the average $(m-1)$ new electron-hole pairs. The generated electrons will flow toward the emitter and become

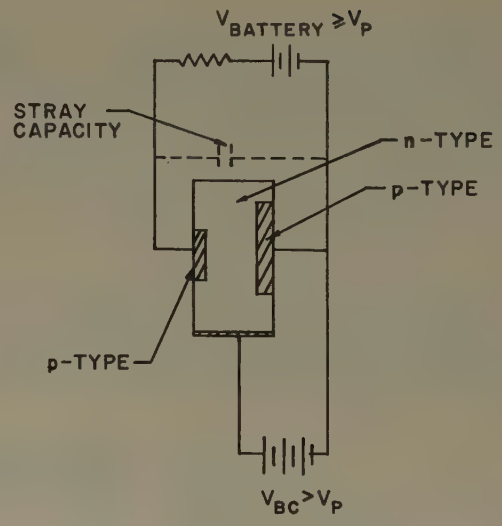


Fig. 7—A circuit for the observation of relaxation type oscillations.

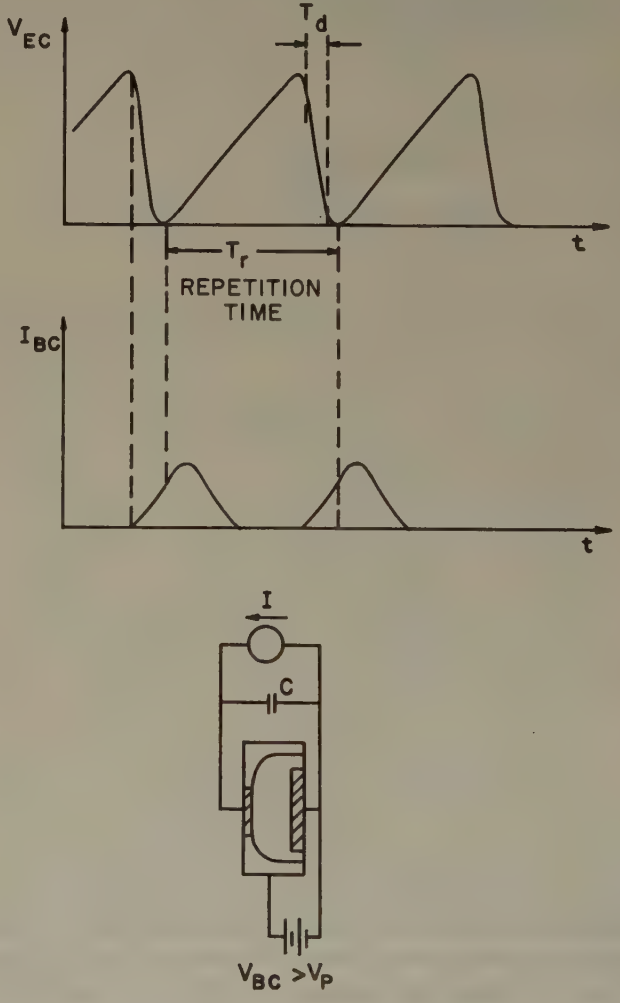


Fig. 8—Emitter to collector voltage and base current as a function of time for the circuit shown.

trapped in the potential energy minimum. Since the electric field at the emitter junction has no component parallel to this junction, the trapped electrons will move to the sides of the emitter by diffusion. The dimensions of the CK762 emitter are large enough (di-

ameter equal to 2.5×10^{-2} cm), so that the removal of these electrons proceeds rather slowly. The possibility that electrons flow into the emitter can be discarded for the reason that the concentration of c_1 of electrons at the potential-energy minimum and the concentration c_2 at the base side of the emitter are related as follows:

$$c_1 \approx c_2 e^{\Delta E/kT},$$

where ΔE is the potential energy difference between the emitter and the potential minimum for an electron in the conduction band; k is Boltzmann's constant; and T is the absolute temperature.

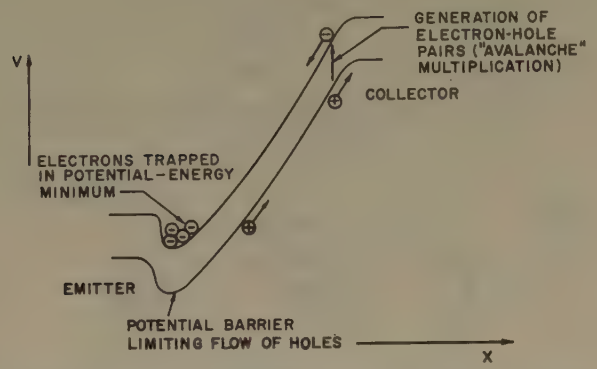


Fig. 9—Plot of energy bands along a line connecting emitter and collector after punch-through.

Since the emitter is field free, any electrons which enter must travel by diffusion. An electronic emitter current as low as 1 microampere requires a concentration of approximately 10^{12} electrons per cm^3 at the base side of the emitter, assuming a lifetime of 10^{-5} second for the electrons. For a potential barrier of 0.5 ev, a concentration of more than 10^{20} electrons/cm^3 is required at the potential-energy minimum. For higher currents, the concentration requirement becomes correspondingly greater. A very high concentration, of course, will alter the potential distribution and long before such a concentration is reached, the potential minimum model (Fig. 9) will no longer apply.

As electrons in the potential barrier become trapped, the barrier for hole flow will be lowered. This increased flow of holes creates more electrons, and the electrons in turn give rise to a still higher hole current, etc. This process permits the hole current to build up to a very high value. A criterion of such an instability can be postulated as follows: Let one hole create $(m-1)$ electrons. Suppose now that an electron, while it is in the potential minimum, induces the flow of f additional holes (for simplicity f is assumed to be constant). These holes in turn will create new electrons and these electrons, new holes, and so forth. The additional number of holes that are induced to flow because of the first injected hole is given by the infinite series:

$$\begin{aligned} N &= (m-1)f + (m-1)^2f^2 + \cdots \\ &= (m-1)f/[1-(m-1)f]. \end{aligned} \tag{3}$$

This series diverges if $(m-1)f \geqq 1$ which means physically that the current builds up rapidly with time. Eq. (3) explains why the device is stable for low values of m, since a stable condition corresponds to $(m-1)f<1$.

Once the capacity begins to discharge through the device, Fig. 9 is no longer applicable, since the potential drop between emitter and collector has dropped below V_P, which implies that the space charge does not extend throughout the region between emitter and collector. In Fig. 10, the space-charge regions are shown schematically. There is a region in front of the emitter which is virtually field-free. The trapped electrons, which were generated at the collector, not only neutralize the positive donors but also holes which are present in this region. Some electrons probably flow out through the "pinched-off" channel between the space-charge regions adjacent to the emitter and collector.

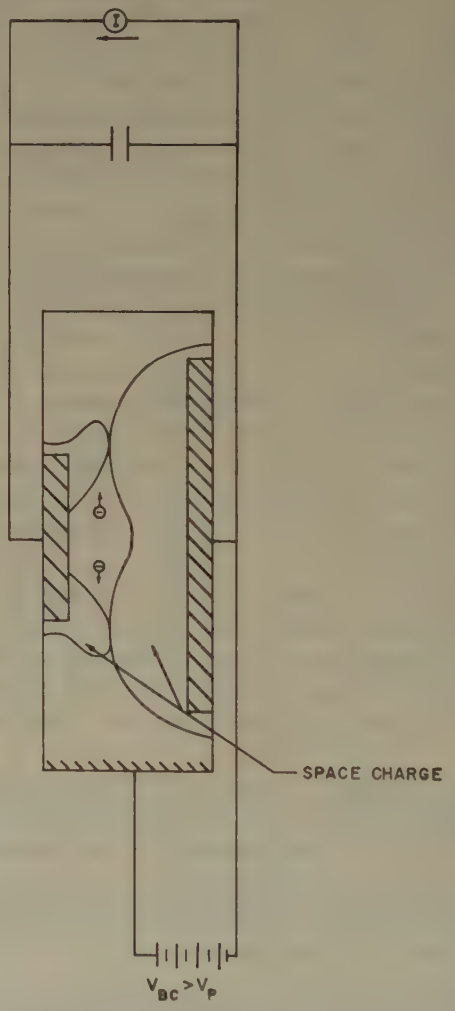


Fig. 10—Scheme of space charge around emitter and collector during discharge of capacity.

From experimental data, rate of flow of electrons through this channel is less than rate at which electrons are created by the avalanche process. Thus, most of the electrons generated near the collector are trapped in front of the emitter junction. To test the above model, a calculation of the discharge time will be made.

Estimate of the Discharge Time

In a regular p-n-p transistor the current I flowing from emitter to collector is given approximately by

$$I_{EC} = AD_p q p_0 / W. \tag{4}$$

Here, A is the emitter area; D_p, the diffusion constant for holes; q, the electronic charge; and p_0, the density of holes in the base region at the emitter side; and W, the width of the base region or, more exactly, the distance between the base-side boundaries of the emitter and collector space-charge regions. The total charge of the excess holes in the base region is given by

$$Q_h = \frac{Aqp_0W}{2}. \tag{5}$$

From (4) and (5),

$$I_{EC} = \frac{2D_pQ_h}{W^2}. \tag{6}$$

During the discharge interval the hole current is large, therefore, so-called high-injection conditions exist. The total electronic charge Q_e in the base region is approximately equal in magnitude to the hole charge Q_h, since the charge arising from the ionized donors can be neglected. Thus

$$Q_e \approx Q_h. \tag{7}$$

From (6) and (7),

$$I_{EC} = 2D_pQ_e/W^2. \tag{8}$$

The width W is related to the voltage difference between emitter and collector. If the distance between the geometrical emitter and collector junctions is l then the punch-through voltage is

$$V_P = \frac{\rho l^2}{2\epsilon} \tag{9}$$

where ρ is the charge density of the ionized donors and ϵ, the dielectric constant. When the voltage between emitter and collector has decreased from V_P to $V_P - V'$, the following relation

$$V_P - V' = \rho\frac{(l-W)^2}{2\epsilon} \tag{10}$$

exists, from which one obtains

$$\frac{W}{l} = 1 - \sqrt{1 - V'/V_P}. \tag{10a}$$

I_{EC} is related to the rate of discharge of the capacity C as follows:

$$I_{EC} = C\frac{dV'}{dt}. \tag{11}$$

From (8), (10a), and (11) it follows that

$$C\frac{dV'}{dt} = 2D_pQ_e/l^2(1 - \sqrt{1 - V'/V_P})^2. \tag{12}$$

If it is assumed that Q_e is the total electronic charge generated near the collector and that none of this charge has passed to the base, then

$$Q_e = \int_0^{V'}[m(V') - 1]dQ_h = C\int_0^{V'}[m(V') - 1]dV'. \tag{13}$$

In the above, the small fraction of injected holes which are needed to maintain the neutral region have been neglected. Using

$$m(V') = \frac{1}{1 - \left(\dfrac{V_P - V'}{V_A}\right)^n} \tag{14}$$

given by Miller,[12] where for 0.5 to 1 ohm cm n-type germanium n is approximately equal to three, the integral becomes

$$\frac{Q_e}{CV_P} = \int_0^{V'}\left(\frac{V_P - V'}{V_A}\right)^3 \left[1 - \left(\frac{V_P - V'}{V_A}\right)^3\right]^{-1}\frac{dV'}{V_P}. \tag{15}$$

This integral is plotted in Fig. 11 as a function of V'/V_P, with V_P/V_A as a parameter.

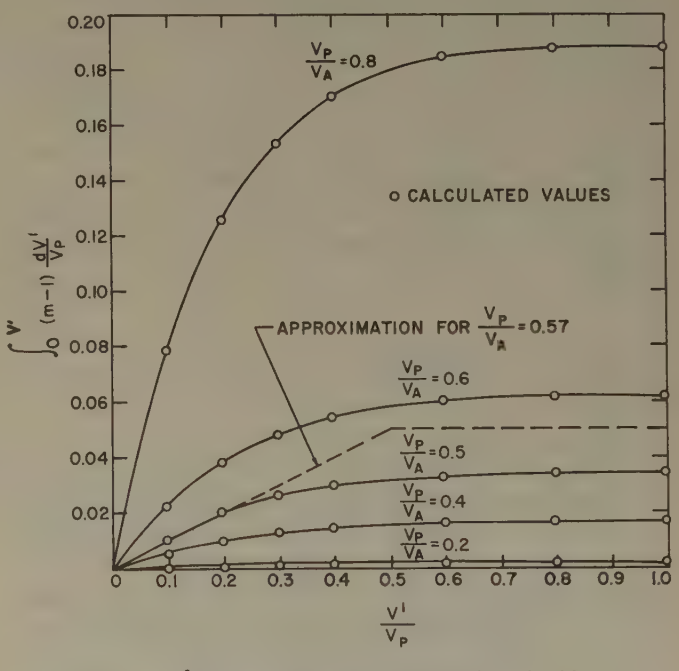


Fig. 11—$\int_0^{V'}/(m-1)\,dV'/V_P$ as a function of V'/V_P for various values of V_P/V_A.

In the investigations, a transistor with $V_P = 24$ volts and $V_A = 42$ volts was studied extensively. For this case, $V_P/V_A = 0.57$. Eq. (12) has been integrated analytically for the dashed curve in Fig. 11, and V_{EC} was obtained as a function of time. The result is shown in Fig. 12. The discharge time is seen to be about 3×10^{-9} second. It is interesting to note that in the calculations, the quantity C drops out [as may be seen by inserting (13) in (12)]. Experimentally, it is found that the discharge time depends to some extent on the capacity. Experimental results for the discharge time as a function of capacity are shown in Fig. 13 for the transistor being

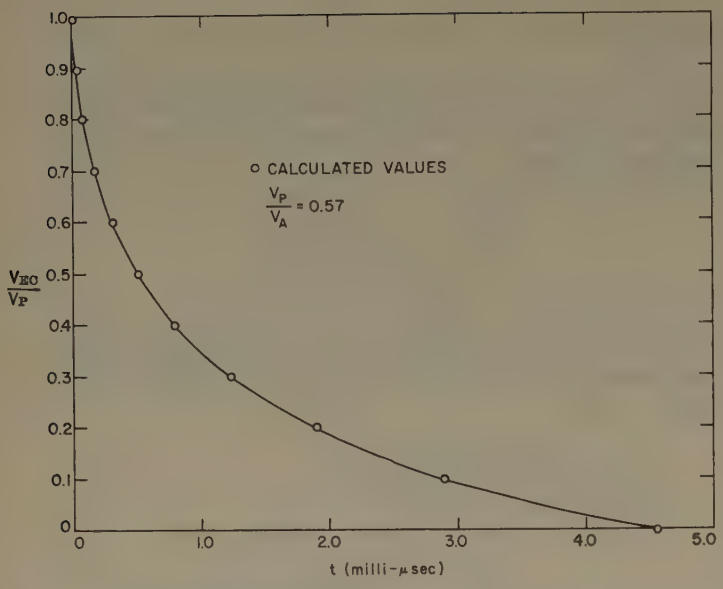


Fig. 12—V_{EC}/V_P as a function of time during discharge of capacity for a transistor with $V_P/V_A=0.57$.

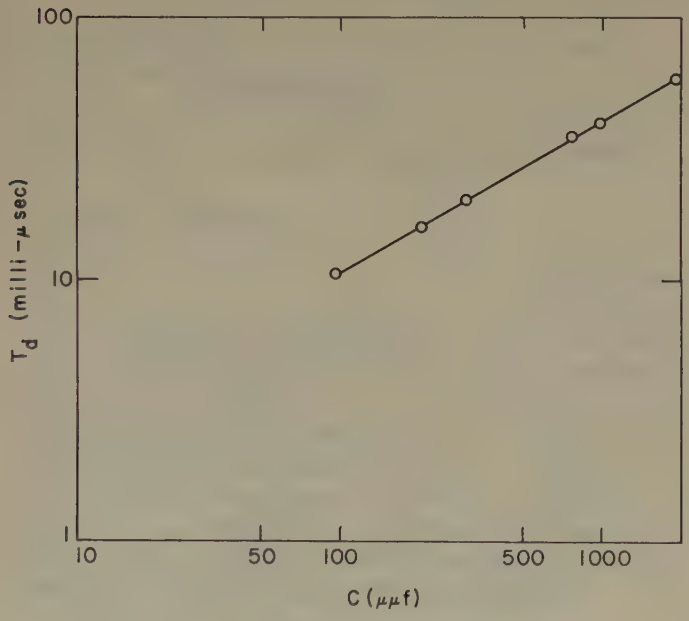


Fig. 13—Observed discharge time as a function of the capacity between emitter and collector.

considered. Because of limitations in the available equipment, values for the discharge time T_d below 10^{-8} second could not be measured. It may well be that for very small capacities, the experimental and theoretical values may approach each other very closely.

It should be mentioned that an abrupt change in the behavior of the devices does not occur when the collector voltage is decreased below the punch-through value. Oscillations have been observed at voltages as low as 0.7 V_P. In this case the oscillations begin because the extrinsic base resistance is large and α is greater than unity. After the capacity is partially discharged the two space-charge layers from emitter and collector touch and the discharge process described above is repeated. The voltage V_{EC} still goes to zero, which can never occur in a circuit having a regular transistor with α greater than unity and a large external base resistor.

Conclusion

The above example of a transistor-like structure shows that in these devices where the injection of carriers into space-charge regions and the avalanche multiplication are used simultaneously, the problem of the accumulation of generated carriers in front of the emitting contact is serious. A similar problem may also arise in the first diode structure discussed if the dimensions of the emitting bond are too large. In the transistor-like structure, tendency of accumulation may be reduced by decreasing the size of the emitter.

In addition, this tendency may be reduced even further by using the deflection produced by a magnetic field. Fig. 14 shows the path of electrons and holes when

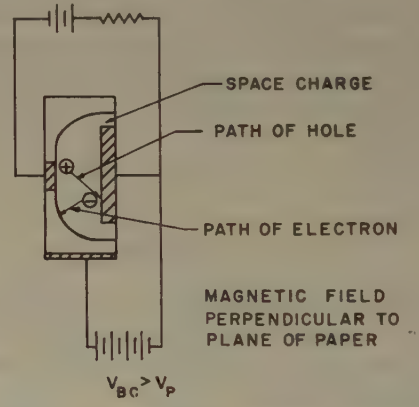


Fig. 14—Path of electrons and holes in a magnetic field.

a magnetic field is applied. The angle θ which the electron current, for example, makes with the direction of the electric field is given approximately by the formula

$$\tan\theta = \mu_n H/c. \qquad (16)$$

μ is the mobility of electrons in esu, which is assumed to be constant; H, the magnitude of the magnetic field in emu; and c, the velocity of light. For $\mu_n=3600$ cm²/volt second and $H=2\times10^4$ oersted, $\theta\approx36°$. In applying (16), however, the dependence of μ_n on the electric field should be taken into account.

At present, it appears that the combination of a small emitter and a magnetic field may result in a useful amplifier. It is important that the relation between V_{BC} and V_{EC} shown in Fig. 4 is maintained. For small emitters, deviations from the relationship shown in Fig. 4 are expected. In practical units a compromise must be made regarding the size of the emitter.

Acknowledgment

The authors thank John Linvill from Stanford University for discussions regarding the relaxation-type oscillations of the transistor-like structure.

Ferrite Apertured Plate for Random Access Memory*

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Summary—**Plates with an array of apertures molded from rectangular loop ferrite can be used for random access memory. With the relatively close center-to-center spacing equal to twice the hole diameter there is negligible interaction between adjacent holes. The nonconductive ferrite plate can be coated with a conductive pattern to form a "printed" winding linking all holes in series. The plates can be stacked and the whole stack threaded with word address selecting wires. The printed windings serve for reading and writing the digits of the word.**

An experimental prototype plate was developed. It has 256 holes of 0.025 inch in a square 0.830×0.830 inch. A current of 330 ma reverses the magnetization around a hole in 1.5 μsec and produces 30 mv. The hysteresis loop has good rectangularity and the properties of the holes are uniform within ±5 per cent.

The memory plates can be driven by a switch, itself made of plates. Several novel switching principles are proposed: switching over all holes of a switch-row but the selected one, using memory plates in pairs, and operating by a flux-limited fashion. This results in read-out signals free of disturbs, fast access, and large operating tolerances. Conventional current coincident operation is possible also.

The making, testing, and assembling of ferrite memory plates with printed windings requires much less time and labor than corresponding techniques with conventional cores. The plates open possibility of random access memories with capacities of millions of bits.

Introduction

TO STORE digital information, it is natural to provide a discrete cell for every bit. This was not the case in most of the early solutions to the problem of the high-speed memory of reasonably large storage capacity—acoustic delay lines and electrostatic storage tubes—which resorted to storing the bits on nonsegregated areas of a homogenous medium. The advent of magnetic materials with fast switching and square hysteresis loop provided the first practical means of building relatively large numbers of individual storing cells, each being merely a tiny toroidal core.[1–3] The core memory proved much more reliable and better in most respects than the earlier types and is now the classical solution to the problem.

The two directions of magnetic remanence provide natural storage for a bit of information and the square hysteresis loop allows the storing magnetic element itself to participate in the switching required for its selection in a memory system. Some years ago when we first realized that these properties were ideal for a large capacity high-speed random access memory, we sought various artifices to fabricate at once arrays of large numbers of cells. At first we used individual cores mostly to test the ideas of complete memory systems. We found that the making, testing, and assembling of individual cores was not too laborious a task as long as the number of cores was in the hundreds or even thousands. The fact is that, with presently well-evolved techniques, the cost of assemblies with thousands and even hundreds of thousands of cores is comparable to the cost of the auxiliary electronic equipment required for operating the memory. But for larger storage capacities, millions or scores of millions of bits, the fabrication, the testing, and the assembly of separately made individual cores becomes prohibitive.

For this reason, the original investigations for ways to fabricate whole arrays of storage cells was carried on, along with experiments with single cores. Some years ago, we conceived the idea of molding a plate with an array of holes out of ferrite material having a square hysteresis loop. Such a plate can provide the many storage sites inherent in the use of a continuous medium and yet preserve the distinctiveness of the cells. This is because the areas on the plate are artificially defined by the apertures to form separate storing cells. Pierced metal sheets were considered by R. C. Minnick and R. L. Ashenhurst.[4] These authors believed it preferable to etch out individual toroids from a sheet cemented on a bakelite support.[5]

The development of our apertured plate has now reached a stage which opens possibilities of memories of very large capacities—millions of bits. Because it requires much less driving power, it promises also to reduce and simplify the associated electronic circuits. Furthermore, it makes possible very compact memories of relatively small capacity.

This paper describes the principle of operation of the aperture plate, its fabrication by molding, means of making printed windings, and the characteristics of an experimental prototype plate with $16\times16=256$ apertures of which thousands were made. A system is proposed to drive the memory plates by a switch, itself made from plates. The operation of the system is based on several novel switching methods which make possible large storage capacities, read-out signals free from disturbs, fast access, and large tolerances in the amplitudes of the electronic driving circuits. The use of the plates in a conventional current coincident operation is considered.

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[2] J. A. Rajchman, "Static magnetic matrix memory and switching circuits," *RCA Rev.*, vol. 13, pp. 183–201; June, 1952.

[3] J. A. Rajchman, "A myriabit core matrix memory," PROC. IRE, vol. 41, pp. 1407–1421; October, 1953.

[4] R. C. Minnick and R. L. Ashenhurst, "Multiple magnetic storage systems," *J. Appl. Phys.*, vol. 26, pp. 575–577; May, 1955.

[5] Since the writing of this paper the author has learned of the work of R. H. Meinken, "Characteristics of a Memory Array in a Sheet of Ferrite," reported at the Conference for Magnetism and Magnetic Materials, Boston, Mass.; October 18, 1956.

The Apertured Plate

Consider a regular array of round holes in a plate of magnetic material having a perfect square hysteresis loop. Let the direction of remanent magnetization around each hole store one bit of information. It should be expected that each hole acts independently as though it were the hole of an individual core, and that there is no effect due to repeated access to adjacent holes. This is for the following reason. For a given current linking an aperture the magnetizing force H diminishes gradually with distance. Near the hole, nearly perfect radial symmetry can be assumed, so that the H lines are circles and the value of H is inversely proportional to the radius. Therefore, there will be some circle of radius R_0 within which the magnetizing force is more than some critical value H_0 required to reverse the flux in square loop materials and beyond which it is less than this critical value. Hence, there should be complete reversal within the circle and none without. For a judicious choice of the energizing current, bringing this circle to less than half the width of the legs separating adjacent holes, there should be no interaction between adjacent holes.

In reality, there is a family of hysteresis loops and the loops are not completely square so that there is a gradual rather than a discontinuous radial change of flux. To determine whether these deviations from perfect rectangularity would produce detrimental "cross-talk," a number of experimental plates were made, all of as identical a material as was possible to make. Each plate had an array of 9 holes of a given diameter d and spaced at a center-to-center distance D, the ratio d/D being different for the various plates (Fig. 1). The current I_0 in the center hole was adjusted in every case to produce maximum discrimination under the conventional two-to-one current regime. The percentage change in the signal obtained from the excitation of I_0 as a result of repeated excitations of an adjacent hole by a current I_1, made equal to I_0, was taken as a measure of the interaction. It is apparent from Fig. 1 that the interaction becomes significant only when the holes are so close that the distance between hole peripheries is less than the radius of the holes. The current producing optimum discrimination is seen to increase linearly with hole size except for a slight deviation from linearity for large holes. The resulting output voltage curve also starts by rising linearly with hole size because the optimum current renders the cross section area of the material in which flux reverses proportional to the hole diameter. The voltage reaches a maximum and then decreases as the available cross section area diminishes because the legs between adjacent holes become thinner. The curve of maximum discrimination rises, first slowly, then more rapidly. This is because the region where flux reverses, between the aperture and its nearest neighbors, becomes thinner; therefore the hysteresis loop, which is an average of elementary zonal hysteresis loops, is squarer as the averaging extends over a smaller radial spread.

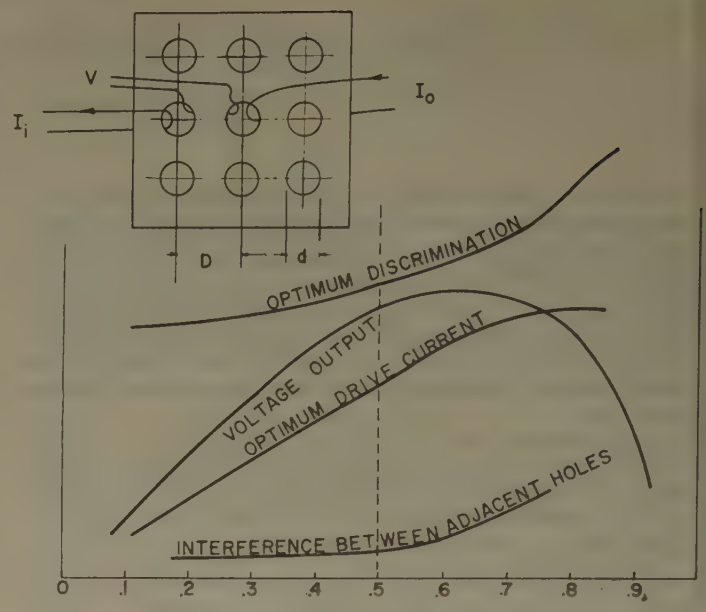


Fig. 1—Effect of hole size and spacing. Ratio of hole diameter to hole spacing.

Because of unavoidable differences in the nature of the material of the various plates and the difficulties of measurements, no absolute numerical significance can be attached to the plots of Fig. 1. However, these plots indicate the general behavior of the interaction, amount of useful signal, and discrimination, as a function of the geometry of the array. The ratio of hole diameter d to hole spacing D of one half is approximately in the center of an optimum range for which there is practically no cross-talk, the signals are high, and the discrimination is relatively large. This simple ratio was adopted for an experimental prototype plate.

The Experimental Prototype Plate

A prototype plate design was adopted for most of our experiments. The plate has an array of $16\times16=256$ holes. The holes are 0.025 inch in diameter and are spaced 0.050 inch center-to-center. The plate is a square 0.830×0.830 inch. (See Fig. 2.) The plates were molded with the array of holes. This required fairly elaborate punches and dies. Considerable experimentation was necessary to develop the right powder, composition, binder, and consistency to obtain satisfactory molding and satisfactory magnetic properties. The firing of the plates is somewhat more critical than the firing of individual cores. This is mostly because precaution must be taken to keep the temperature uniform throughout the area of the plate. Prefiring in tunnel-type furnaces in air, followed by final firing in controlled atmospheres, yielded uniform plates with fairly square loop characteristics. These characteristics are described in more detail below.

The Printed Winding

The ferrite plate is nonconducting, in fact a fairly good insulator. It is possible to coat it with a metallic

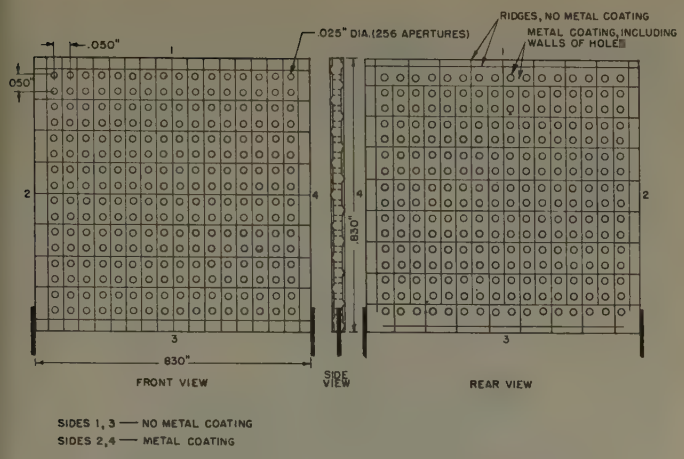


Fig. 2—The experimental prototype apertured ferrite plate.

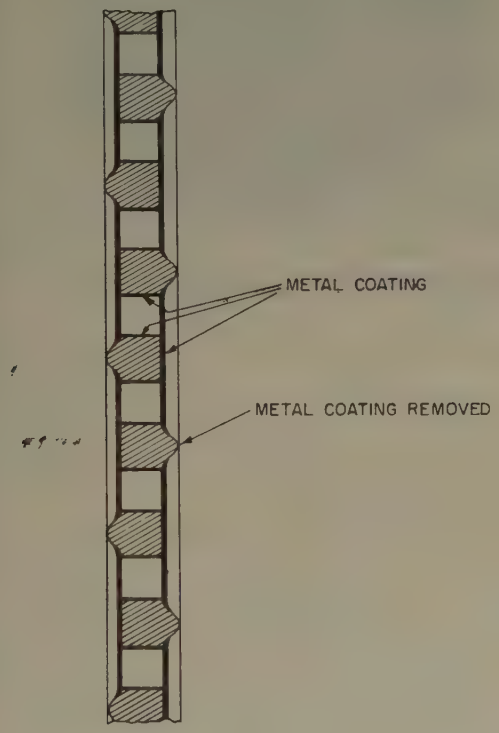


Fig. 3—Enlarged cross section of ferrite plate.

conductive layer so as to link the holes and thereby obtain a "winding" without the necessity of threading a wire through the holes. This method is particularly suitable for making a winding which links all the holes in series. To obtain such a winding the ferrite plate is first coated with a metal conductive layer on its entire surface including the inside walls of the holes. Then, the coating is removed along cross-lines so that little islands of metal remain on the surface of the plates. (See Figs. 2–5.) Each island is a rectangle comprising two holes. The rectangles on one side of the plates are staggered with respect to those on the other side. The continuity of current flow is, therefore, through one island, then through the coating of the walls of the hole, then through the island on the other side, back through the coating on the walls of the next hole to the next island, etc. (See Fig. 3.) The pattern of islands is so

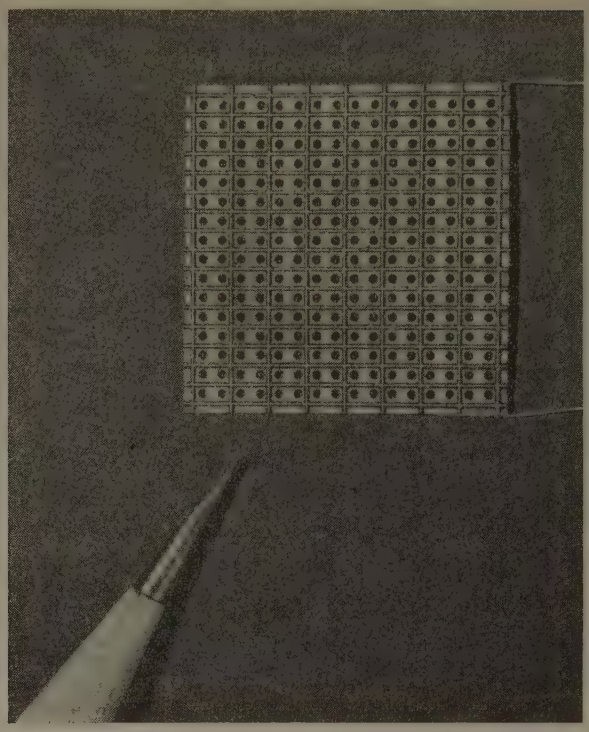


Fig. 4—Photograph of experimental prototype memory plate with an array of $16 \times 16 = 256$ apertures.

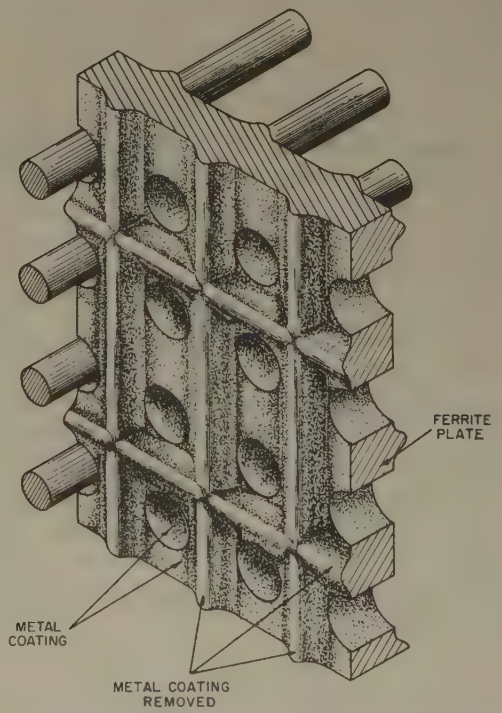


Fig. 5—Perspective view of section of prototype plate.

designed that a winding, linking all holes in series, is obtained. The removal of the metallic coating along appropriate straight lines can be done in various ways such as grinding grooves, using photo-engraving techniques, etc. A particularly convenient method is to mold the plates with a pattern of ridges corresponding to the lines along which the coating is to be removed. These ridges are only a few thousands of an inch high. After

spraying the entire surface of the plate it is merely sufficient to remove the metal coating on the top of the ridges to obtain the desired pattern. Fig. 4 is a photograph of the plate with its printed winding. The two terminals are 0.007-inch bare copper wires, silver pasted to two sides of the plate. (Slides 2 and 4 on Fig. 2.) The silver on the two other sides (1 and 3) of the plate is removed to prevent a short between the terminals.

The plates undergo considerable shrinkage during firing, about 20 per cent in linear dimensions. The exact final size depends on the nature of the ferrite, the pressure of molding, and the heat treatment. It is found to be remarkably constant, perhaps within ± 0.001 inch for the 0.830-inch side of the plate, provided accurate control of parameters is maintained. But during the developmental stage, when different materials and processing are used and the size may vary considerably, the ridges are a particularly convenient way of insuring that there is no misalignment between the pattern of lines and the pattern of holes. The ridges have also another important advantage in that they tend to strengthen the plate, particularly when it is very thin. Plates were made with a thickness of only 0.007 inch at the significant location around the holes, although a thickness of about 0.020 inch was selected for the prototype plates.

Plate Testing

After being provided with its printed winding, the entire plate can be tested easily in a single operation by means of a special tester. The tester has an array or "forest" of parallel conductors over which the plate is inserted. The electric circuit of the conductors is closed by shorting the conductors after insertion of the plate. The pins are energized serially by means of a magnetic switch, itself made of plates (of a type described below). The outputs from the successive holes are obtained from the printed winding and are conveniently displayed as a superposition of traces on an oscilloscope. A glance at the bundle of traces suffices to determine whether or not the plate is acceptable. An experimental semiautomatic tester was built (Fig. 6) which had only 128 pins so that two insertions are necessary to test the whole array of 256 holes.

Plate Characteristics

Many thousands of prototype plates were fabricated in an experimental batch. Fair uniformity was observed on sample tests of about a hundred plates each. Typically, the amount of flux reversed around the aperture for a given current excitation varied ± 5 per cent from the average, within a given plate as well as between plates.

The operation under the conventional two-to-one current drive is shown on Fig. 7. An aperture was energized by a train of current pulses



Fig. 6—Semiautomatic experimental plate tester (photo).

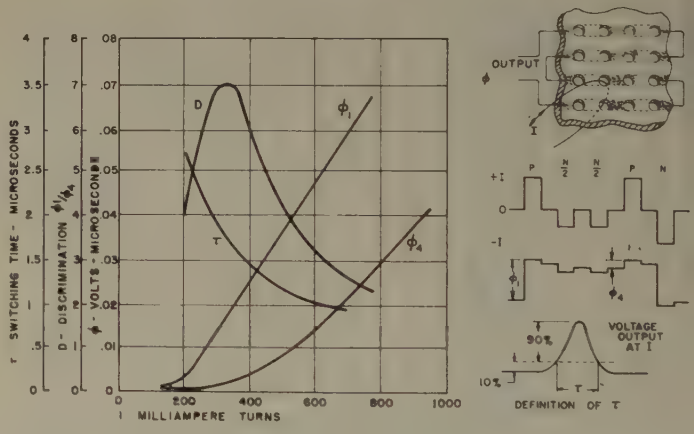


Fig. 7—Flux changes, discrimination, and switching time around aperture of prototype plate.

$$\left(P\frac{NN}{22}PN \text{ as shown on Fig. 7}\right)$$

used in routine checking of discrimination for conventional cores. The wanted flux reversal ϕ_1 for a given current excitation and the unwanted disturb flux ϕ_4 obtained after two disturbs of half the given current excitation are plotted as a function of the current excitation. These flux reversals do not include the reversible part subtracted at the end of the current pulses and thus include both reversible and irreversible flux changes. The ratio of wanted-to-unwanted fluxes ϕ_4/ϕ_1 exhibits a maximum for an excitation of about 330 ma. The switching time τ is plotted also as a function of I and is seen to be about 1.5 μsec for the nominal excitation of 330 ma.

Read-out signals obtained from the printed winding are shown by the photograph of oscilloscope traces on Fig. 8. The full current was at the nominal amplitude of 330 ma. The wanted signal 1 occurs at the first positive P pulse, the disturb signal 4 of interest occurs at the second positive P pulse after two half amplitude negative demagnetization pulses. The discrimination of this experimental ferrite plate is comparable to that of early cores and somewhat inferior to that of present day relatively evolved cores. On the other hand, the aperture of the plate requires about 3 times less current and only about 2×10^{-8} joules or about 5 times less energy than the conventional memory core. This economy results from the fact that it is practical to use only a very small volume of material in a plate of manageable dimensions, while an individual core of the same volume would be unmanageably small.

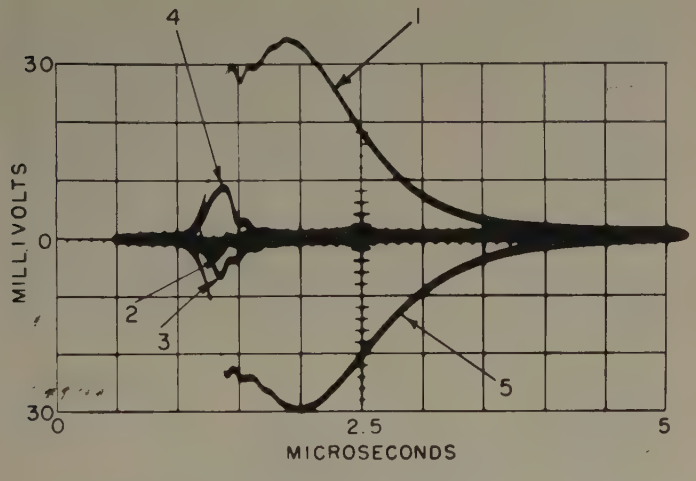


Fig. 8—Read-out signals from the aperture plate.

The observed amount of "cross-talk" between adjacent holes of the prototype plate is very small, as illustrated by the plots of Figs. 9 and 10. The spread of flux from an energized aperture outward is apparent on Fig. 9 which is a plot, as a function of current amplitude, of the total flux ϕ_1 around the aperture, the flux ϕ_2 in the region up to the nearest adjacent holes, and finally of flux ϕ_3 in the next surrounding zone. This spread is as should be expected by assuming that the flux reverses up to a critical circle of radius proportional to current. If the current is kept below the value for which the circle bisects the leg between adjacent holes, there should be no interaction, as was mentioned. This is verified approximately by the measurements of the variations of flux in a leg between two adjacent holes as a function of current excitations in one and then the other hole, as shown on Fig. 10. The entire plate is first brought to a standard condition of flux distribution by a current I_0 through the printed winding (directions of flux around the holes in a checkerboard pattern). Then a current I_1 is applied through one of the holes and produces a flux change ϕ_A in the intermediary leg. If, before the flux is restored by a new pulse I_0, a pulse of current

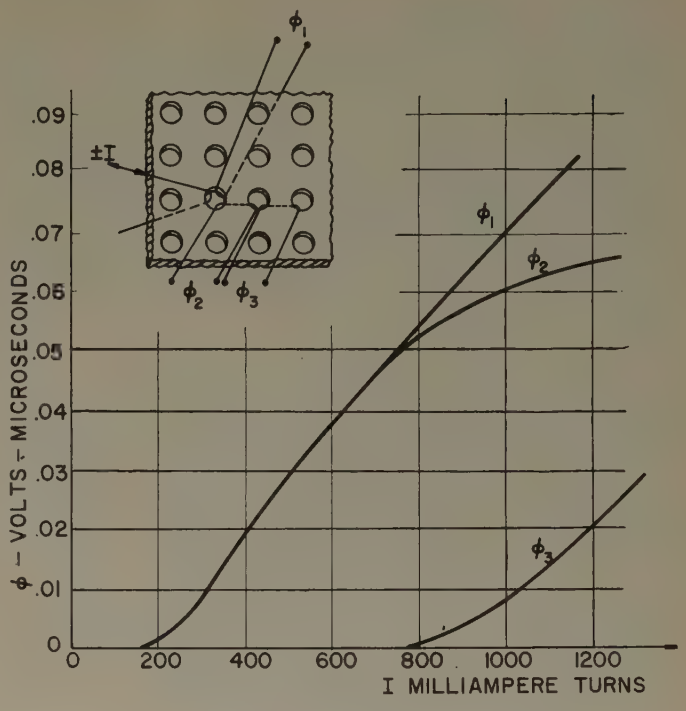


Fig. 9—Flux spread in apertured plate.

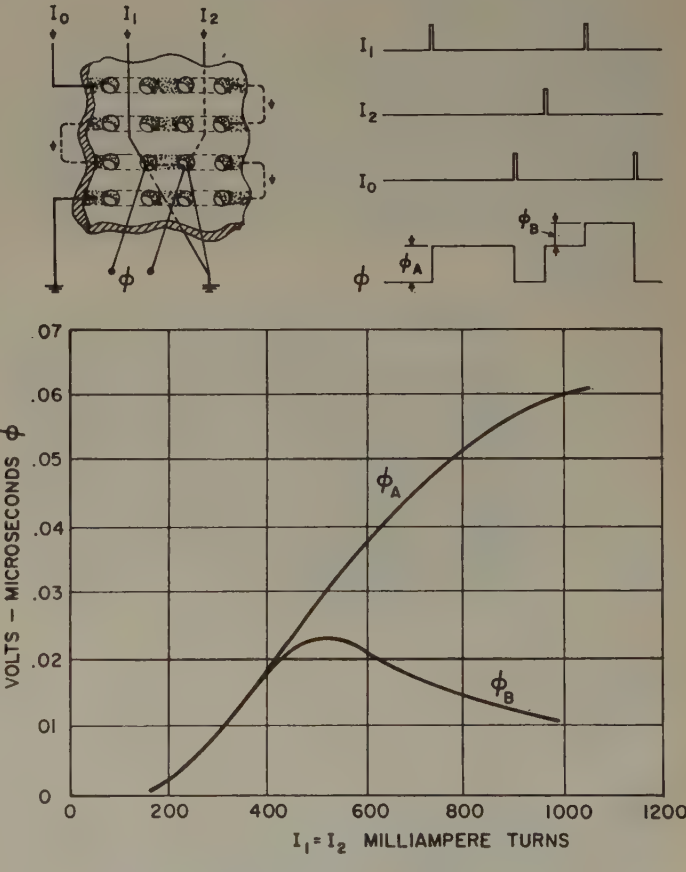


Fig. 10—Effect of access to adjacent hole.

I_2 (equal to I_1) is applied to the other hole, the resultant flux change ϕ_B in the intermediary leg has not, in general, the same value as ϕ_A, since some of the flux in that leg was previously reversed by the pulse I_1. However, the values of ϕ_B and ϕ_A are almost identical for values

of current that produce about half the total possible flux change in the intermediary leg. For the optimum operating current of about 330 ma, the value of ϕ_B is only slightly less than ϕ_A, showing that there is only negligible cross-talk between the apertures which, for all practical purposes, can be considered to operate independently. A considerably larger current, about twice the optimum value, may still be used, even though it will reduce, in general, the strength of the signal obtained from an adjacent aperture.

Current Coincident Plate Memory

For most applications of high-speed memories, random access to a word composed of a number M of bits is desired. This number M is typically between a few and a hundred. The plates are particularly suitable for such a parallel memory as they are conveniently stacked with all their apertures in perfect register. The stack is wired as a unit with address selecting wires so that the same location in each of the M plates (or plate pairs) is reached simultaneously. The printed or "digit" winding on the individual plates serves for read-out and write-in of the digits of the word.

The plate memories can be operated in a current coincident mode, just as do the conventional core memories. The holes of the stack of plates are threaded back-and-forth by rows X and columns Y, as shown on Fig. 11. This threading is not too exacting a task, even though the holes are only 0.025 inch or half the ID of conventional memory cores, because the wires go straight through the holes which are in perfect axial register.

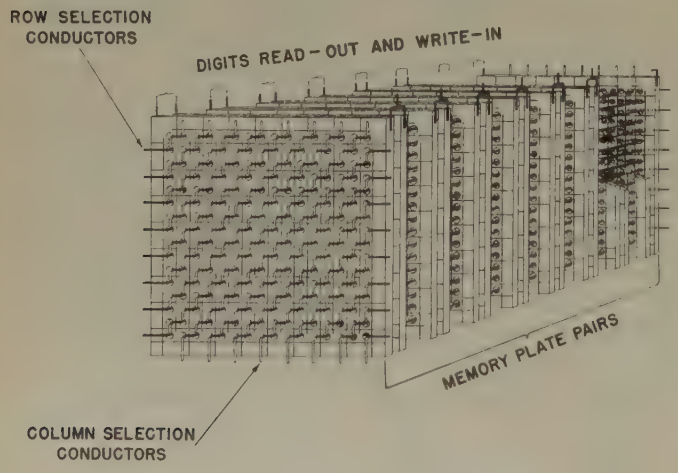


Fig. 11—Current-coincident ferrite plate memory.

This wire threading is a unique operation and need not be repeated separately for each plane, as is customary with memory core planes. The numerous separate digit windings, so tedious to thread in core planes, are obtained by the printed technique on the plates. It is apparent therefore that the complete "wiring" of the stack of plates is much simpler than with individual cores. However, only three conductors are provided in each aperture: the printed digit Z winding in the form of metal coating on the wall of the hole and the X and Y selecting wires. It is not convenient (although possible with a modification of the printed technique) to provide two digit windings, one for read-out and one for write-in, as is customary with core planes, so that the single Z winding must serve for both functions. This poses some problems.

It will be recalled that in most current-coincidence operating modes there are two cycles: a reading cycle in which the selecting wires X and Y are energized with $+I/2$ and the signal is read-out from the Z winding, and a writing (or rewriting) cycle in which the selecting wires X and Y are energized with $-I/2$ and the Z windings of the various planes are either not energized or energized with inhibiting currents of $+I/2$ depending on the nature of the digits to be written in. The logic of the writing requires that the three windings X, Y, and Z link every aperture in the plate in the same sense. This is achieved by threading the X and Y windings back-and-forth through the stack to conform with the physical checkerboard pattern of the Z-printed windings, as is shown on Fig. 11. Therefore, during the read-out, the voltages induced by the half excitations of the apertures on the selected row and column, add up, rather than tend to cancel each other as in conventional read-out windings, and produce an appreciable masking disturbance. This disturbance could be neutralized by a fixed voltage derived from an auxiliary core excited at the instant of read-out.

A better way to cancel the disturb signals is to use a pair of plates for every digit. A bit is stored by magnetizing around an aperture in one plate in one direction, and around the corresponding aperture in the other plate, in the opposite direction. The Z windings of the plates are connected in series opposition, as shown on Fig. 11. Therefore on reading, the disturb signals of the two plates tend to cancel each other, and the polarity of the net signal is indicative of the stored bit. For writing, the inhibiting current is sent through the Z winding of one or the other plate. The use of a pair, instead of a single plate per word digit, is reasonable and not as extravagant as would be the use of two-core arrays. The cost of the molded plate with its printed winding is inherently low and the doubling of the number of plates has no effect on the labor involved in threading the stack.

To obtain storage capacities with more words than there are holes in a plate, an array of plates can be used for each digit, the Z windings being connected in series. The threading of the X and Y wires in the larger stack of plate arrays can be made in a single operation or by connecting together individually threaded plate stacks. The limit to the possible number of words depends mostly on the method used to overcome the effect of the disturbs. Any of the methods developed for core memories are applicable. For example: strobing at a time where the disturb voltage has decayed and the voltage due to the slower irreversible flux is near maximum, di-

viding the read cycle in two to allow the disturb due the excitation of X to decay before Y is excited, or integrating over a positive and negative excitation cycle. The hysteresis loop of the plates is almost as square as that of the conventional individual cores, but the uniformity of properties between apertures is not quite as good as that resulting from the most severe core segregation, thus a somewhat greater reliance must be laid on the above methods.

Switch Driven Plate Memory

In the early stages of development of the ferrite apertured plate, there was some doubt whether sufficient loop rectangularity could be obtained for operating by current coincidence. A method tolerating poor plate characteristics was devised. It consists of driving the memory plate stack by a switch which energizes the selected word location without half exciting any other locations. In this way the function of address selection is performed by the switch and that of storing by the memory stack. This method is advantageous even when the presently available prototype plates with good rectangularity are used, because the read-out signal is inherently devoid of any disturbances and is simpler to detect, the operation can be faster, and the drives can have larger tolerances.

The address selecting switch is itself made of a stack of plates identical with those of the memory stack, but without the printed windings, as shown on Fig. 12. The

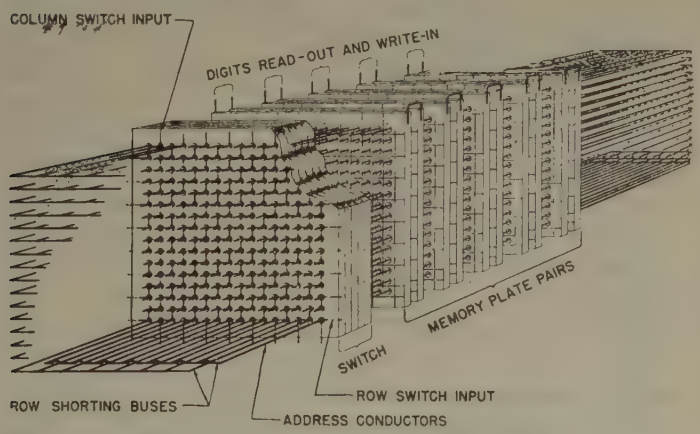


Fig. 12—Switch driven ferrite plate memory.

switch stack is threaded by X and Y windings, and is set in perfect geometrical register with the memory stack. Both stacks are threaded through straight address selecting conductors, one for each aperture. The threading of this "forest" of wires is relatively simple as it amounts to dropping a straight wire into each of the apertures. The ends of these wires are shorted by rows in a manner to be described.

The "end-on" switch can produce outputs on one of the address selecting conductors as a result of the energization of the corresponding row X and column Y in a number of ways. For example, it could be biased with a pulsed or dc inhibiting drive overcoming one of the lines drives, or it could be driven by driving the selected row and inhibiting all columns but the selected one, as was done in previous types of memory driving switches.

A novel method called "set-a-line" was found which has many advantages over previous types. Consider an array of switching elements, cores or apertures in a plate, shown for simplicity as an array of $n \times n$ cores on Fig. 13 ($n=4$). The loads to be driven by the switch

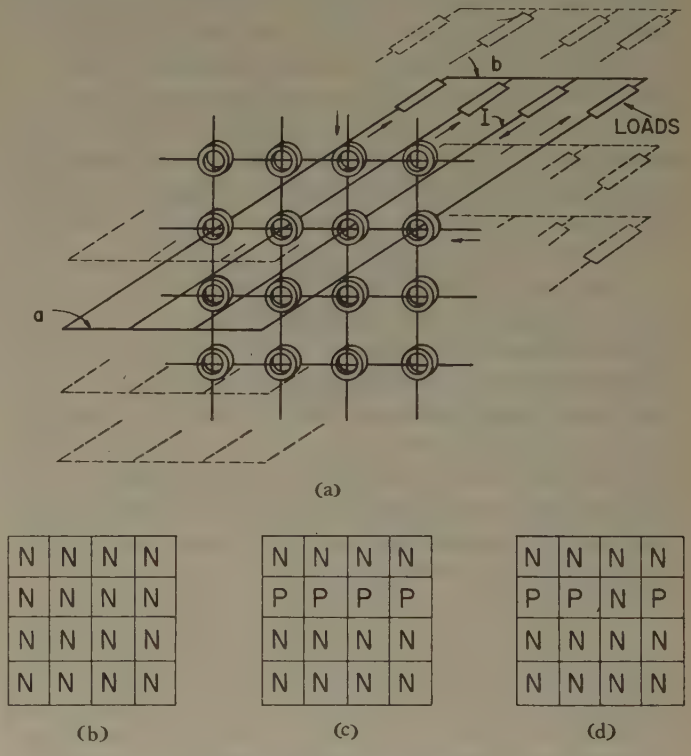


Fig. 13—Operation of set-a-line magnetic switch. (a) and (b) initial; (c) set-a-line; (d) intermediary.

and assumed of equal impedance Z, are connected in parallel by rows, as shown on Fig. 13(a). Let all cores be initially in a normal state N (Fig. 13(b)). In a first step, a current pulse is applied to the selected row tending to drive all cores of the row toward P and at the same time (or with a slight advance) another pulse is applied to the selected column tending to drive all the cores of the column towards N. As a result, all cores of the selected row are switched to the state P, except the one on the selected column which is kept in its initial state by the column inhibiting current. This produces the intermediary pattern of core states, Fig. 13(d). The voltage V_1 induced on the $(n-1)$ cores which are switched over, causes currents to flow in the corresponding loads and returns through the selected load. The equivalent circuit is that of a source V_1 connected in series with the selected loads and the remaining $(n-1)$ loads in parallel. Therefore the current I in the selected load is $+(V_1/Z)(n-1/n)$ while the current in each of the remaining $(n-1)$ loads is $-(V_1/Z)(1/n)$. In a second step, a current is applied to the selected row tending to restore all cores to N. The inhibiting current on the

selected column may or may not be left on during this step. This causes the $(n-1)$ cores which were switched in the first step to switch back and induce voltages V_2 and thereby cause the flow of a current I in the selected load equal to $-(V_2/Z)(n-1/n)$ and a current $+(V_2/Z)(1/n)$ to flow in the remaining $(n-1)$ loads. For both steps the currents in the unselected loads are $(n-1)$ times smaller than the selected load current and therefore negligible in most practical cases when n is fairly large. The rate of change of flux of the switching cores can be made very high as the logic of the switch operation does not depend on the amplitude of the drive row current which can be made as large as desired. Of course, the inhibiting column current must be made consequently larger. Therefore the voltages pulses V_1 and V_2 can be made of high amplitude and short duration. For symmetrical excitation V_1 and V_2 will be symmetrical, *i.e.*, of equal and opposite amplitude. Asymmetrical operation is possible also, yielding a high and short positive pulse followed by a low and long negative pulse or vice versa.

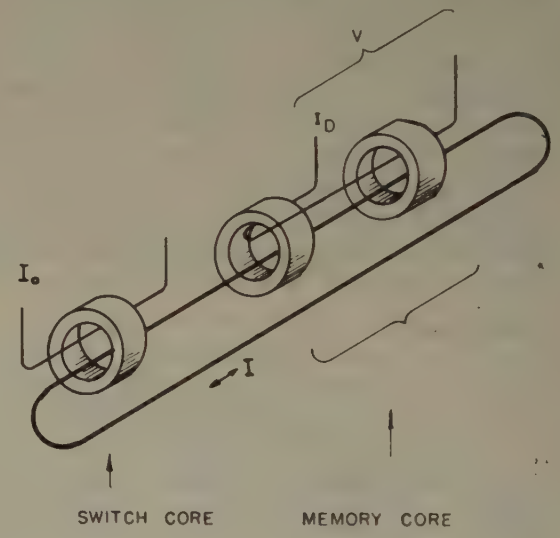
The polarities of energization of the load address conductors must alternate along rows and columns to conform with the checkerboarding due to the printed Z windings of the memory plates. This determines the back-and-forth threading of the row and column windings on the switch and the use of interlaced shorting row buses on the ends of the address conductors, shown on Fig. 12.

It is of interest to note parenthetically that the first operating step could be split in two; a row drive and a subsequent column drive. The row drive switches over or "sets" all cores of the selected row and brings about the pattern of Fig. 13(c). These switch-overs produce a voltage between the shorting buses a and b, but no load currents, as there is no available return path for the current. The subsequent column drive brings about the intermediary state shown on Fig. 13(d) and causes the same currents to flow in the loads as was the case when the row and drive pulses were simultaneous. This mode of operation involves no coincidences of driving currents. It may be useful in cases where the logic of addressing furnishes row information prior to column information.

The switch produces very small disturbing currents in the unselected loads corresponding to the selected row and column. On the row, these currents are due to the fact that the unselected loads are a part of the return circuit for the current of the selected load. They are small for all practical cases when there are many columns (*i.e.*, $n>8$), as was mentioned. On the column, there are small disturbing voltages due to reversible flux changes around the apertures driven further into saturation by the column inhibiting current. Therefore the read-out signal from the switch driven plate memory is almost solely due to the drive of the selected address conductor and is practically devoid of any masking disturbance.

A pair of memory plates is used for every bit of the word. A bit is stored by magnetizing around corresponding apertures of the two plates in opposite directions, in one way or the other. This pairing was proposed for cancelling masking disturbance on read-out in the coincident current operation, but is not necessary for that purpose in the switch drive mode since there are practically no such signals. The purpose of the pairing is primarily to render constant the load presented to the switch by the memory. Irrespective of the nature of the stored word, there will be precisely M apertures around which flux reverses irreversibly and M apertures around which flux reverses reversibly, since in every plate pair the two apertures are left in opposite states.

The use of plates in pairs permits operation of the system in a "flux-limited" fashion. To understand the system consider first the case of three identical square loop cores linked by a shortening loop of negligible ohmic resistance, as shown on Fig. 14. Initially, the



INITIAL	N	N	P
READ	P	N	N
REWRITE OR WRITE	N	N	P

Fig. 14—Flux limited switch drive.

switch core and one of the memory cores are assumed at N and the other memory core at P. In a first, read-out step, the switch core is reversed from N to P by a drive current I_0. Because the ohmic voltage drop in the shorting loop is negligible, the change of flux in the switch core must produce an equal total irreversible flux change in the memory cores and therefore cause the memory core initially at P to switch to N, bringing both cores to N. The polarity of the read-out voltage induced on a digit winding linking the two cores in series opposition identifies which of the two cores switches over. In a second, write-in step, the switch core is restored from P to N by a drive current I_0 of the opposite polarity. At the same time, or preferably with a slight advance, a

current I_D is sent through the digit winding in one or the other direction depending on the digit to be written or rewritten-in. This current I_D favors the turning over of one of the memory cores and hinders that of the other. Consequently the flux from the switch core will be transferred to the memory cores in unequal parts, a larger part to the favored and a lesser part to the hindered core. For a sufficiently large amplitude I_{D0} of the digit write current I_D, all the flux will appear in one of the cores. For smaller amplitudes, there will still be a difference between the fluxes transferred to the two cores and consequently a logical write-in which can subsequently produce a read-out signal of correct polarity even though it is of reduced amplitude.

The example of the three identical cores illustrates the operation at one address of the flux-limited end-on switch driven plate memory system. Let the number of plates making up the switch be such that the maximum amount of flux that can be reversed in the switch be just equal to the amount of flux to be reversed in M memory plates, one for each pair. When plates of the same thickness as the memory plates are used this number is equal to M. Fewer thicker plates can be used also. The elements of the idealized circuit of Fig. 14 are approximated at every location as follows: the switch core by the $(n-1)$ row apertures around which the flux reverses, the shorting loop by the address conductor in series with the $(n-1)$ other conductors in parallel, and the two memory cores by the $2M$ apertures of the memory plates. The circuit includes also the selected aperture of the switch, which does not switch-over during selection, and which adds negligible impedance to the loop.

The flux limited mode of operation has a number of advantages. Because the amount of flux transferred to the memory is strictly limited by that available in the switch, very large drive currents I_0 (and consequently large but short loop current pulses I) can be used to obtain fast switch-over and large read-out voltages for relatively small stored-in write energy. Considerably faster speeds are possible than those obtained with a nominal current adjusted for maximum two-to-one discrimination. There is considerable tolerance in the amplitude of the write-in digit current. This is illustrated by typical plots of the net read-out signal (difference in flux between the two plates of the pair) as a function of that current. (See Fig. 15.) The middle full curve is obtained when the two plates of the pair are identical and the dotted curves are indicative of curves that could be obtained with plates differing in thickness or some other parameter. There is a minimum to the allowable digit write-in current necessary to compensate for possible differences between plates. There is a maximum above which the write-in digit current would produce irreversible demagnetizations in the nonselected apertures of the plate. This maximum is considerably greater than the value for which substantial read-out signals are obtained. The allowable extreme values depend somewhat

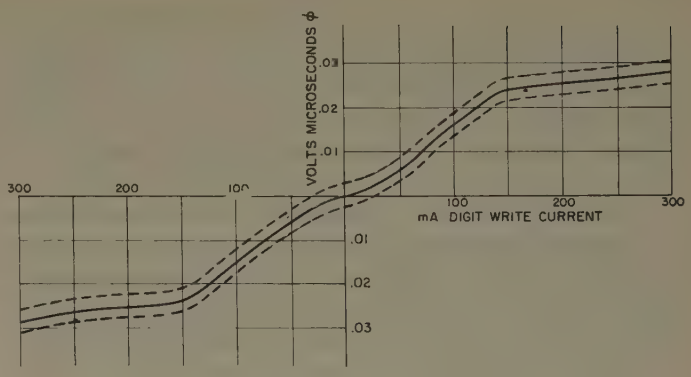


Fig. 15—Output signal as a function of digit write current.

on the switchover time. In practice, there is a tolerance of about two to one in the amplitude of the digit write-in current.

Associated Circuits

The plates are provided with a single digit winding obtained by a fairly simple printed technique. The more complex techniques for "printing" two windings are not necessary because the use of a pair of plates per digit makes it possible to design fairly simple circuits operating on a single winding for both sensing the read-out and writing the desired digit.

Such a typical circuit is shown by the block diagram of Fig. 16. The digit winding is coupled through a trans-

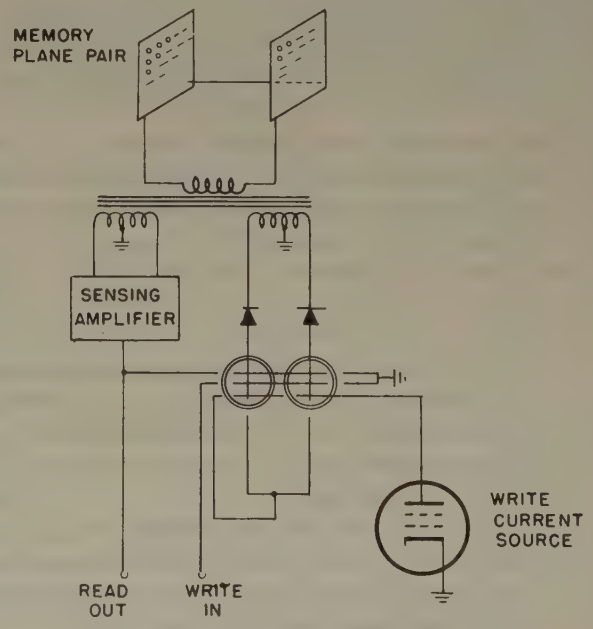


Fig. 16—Digit sensing and writing circuit

former to a sensing amplifier which produces a current of one or the other polarity depending on the polarity of memory output. This current sets an auxiliary pair of square loop cores, one core in state N and the other in state P or vice versa. Rewriting is obtained by steering a current from a driving source through one or another of two windings wound in opposite directions on the transformer and thereby inducing a current in the digit

winding in one or the other direction. During rewrite the sensing amplifier is gated off. For writing new information, the auxiliary cores are set by the write-in signal instead of the sensing amplifier. It is convenient to use transistors for the sensing amplifier and a tube drive current source common to all digit circuits.

The address circuits for the plate memory can be one of the many types used with core memories. In general the requirements are less severe. In the current coincident mode considerably less driving power is required than that required for the core memory, because the energy stored per bit is about 5 times smaller around the aperture of a plate than in a conventional core. Also the smaller amplitude of the row and column currents gives a better match to tubes or transistors. The switch driven plate memory requires more power because the switch itself dissipates power. However, the very large tolerances of the driving currents make possible simpler circuits.

Conclusion

Apertured ferrite plates are proposed for building high speed random access memories. They provide a simple means to fabricate large numbers of discrete storing cells in convenient packages which can be easily assembled into large memory systems. Furthermore, the cells can be made small so as to require little energy to store each bit.

A prototype experimental plate and means to use it in memory systems were developed which realize to a large extent the expectations of this proposal. The findings of the development may be summarized as follows:

1) The prototype is a molded square plate 0.830 $\times$0.830 inch having $16\times16=256$ apertures 0.025 inch in diameter and spaced on 0.050 inch centers. Measurements show that:
   a) There is negligible interaction between apertures.
   b) In lots of hundreds of plates taken from thousands the properties between apertures of a given or different plate are approximately within ±5 per cent of an average value.
   c) The hysteresis loop around each aperture has good rectangularity.
   d) At 330 ma drive the flux reversal around each aperture occurs in 2 μsec and produces a peak voltage of 30 millivolts. The energy stored per bit is less than 2×10^{-8} joules.
2) The fabrication, the testing, and the assembly of the memory plates is relatively simple and economical.
3) The memory plates can be used with conventional two-to-one current coincidence drive. This is particularly suitable for compact, lower power consuming, transistor driven, memories of relatively small capacity.
4) A new method is proposed of driving memories particularly suitable for plates. The memory plates are driven by an "end-on" switch itself made of plates. The switch operates in a "set-a-line" and "flux-limited" fashion and the memory uses plates in "push-pull" operated pairs. This results in a mode of operation permitting fast access, large storage capacities, and allowing large tolerances in the timing and amplitudes of driving currents. The systems of switching developed for the plate memory have broader utility. The use of a pair of memory cores driven by a switch core of limited flux may find applications in fast core memories and logic circuits.

We ventured to predict three years ago[3] that microsecond random access memories with capacities reckoned in millions of bits, megabits, would be available at a relatively low cost in a distant future. We believe that the ferrite aperture plate is now ready to usher in the era of such memories. It will follow the present era of core memories with capacities of hundreds of thousands of bits. But the demand for larger and faster memories is incessant and we may look forward to the development of new techniques making possible storage of billions of bits.

Acknowledgment

The success of this work is due to many members of RCA Laboratories. C. Wentworth developed the plate processing. W. Wales[6] and G. R. Briggs worked in the early phases of the investigation. H. D. Crane[7] and W. F. Kosonocky worked in the later stages and contributed many ideas. A. W. Lo was active throughout the project and developed the sensing circuit. Most of the mechanical work was done by J. Wallentine.[8] B. M. Quinn and C. H. Morris contributed to the shop work.

[6] Now at Cal. Inst. Tech., Pasadena, Calif.
[7] Now at Stanford Res. Inst., Stanford, Calif.
[8] Now at Telemeter Magnetics, Inc., Los Angeles, Calif.



Stability and Power Gain of Tuned Transistor Amplifiers*

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Summary—**The transistor is a nonunilateral device which, if appropriately terminated, can become unstable at frequencies where its "internal feedback" is sufficiently large. At such frequencies, the maximum power gain is infinite and the transistor may oscillate. This paper discusses the maximum power gain realizable as a function of a required degree of stability.**

A "stability factor" is defined in terms of the transistor parameters and terminations (the admittance matrix is used as an example, but the approach is analogous using other representations). The maximum stable power gain of an isolated amplifier stage and the terminating admittances required for the realization of this maximum power gain are then computed as functions of the stability factor. The computations are extended to include bandwidth requirements and limitations. (It is found that, although bandwidth requirements *may* impose limitations on the power gain, there is no simple relationship tying together bandwidth and power gain.) The treatment of multistage amplifiers is outlined with the conclusion that the gain realizable in an n-stage amplifier is smaller than n times the gain of a one-stage amplifier having the same stability factor as the stages of the n-stage amplifier. The respective advantages of different representations for different circuit configurations are discussed.

In an appendix, the theoretical considerations are applied to tuned transistor amplifiers in common-emitter and common-base configurations. The stability factor is related to the tolerances in transistor parameters and terminating impedances. Examples are given for the maximum realizable stable gain as function of parameter tolerances.

Introduction

TRANSISTORS are *nonunilateral* devices; a signal applied to the output port of a transistor amplifier results in a response at the input port. The existence of *internal feedback* is expressed by the fact that, if the transistor is described by the "z," "y," "h," or "g" matrices, the matrix element having the subscript 12 (*i.e.*, z_{12}, y_{12}, h_{12}, or g_{12}) is different from zero.

If properly terminated at its ports, a device having sufficient *internal* feedback may become unstable (*i.e.*, may oscillate) even in the absence of *external* feedback. For example, in the "tuned plate-tuned grid" vacuum tube oscillator, feedback is provided entirely by the grid-to-plate capacitance of the tube.

It has been shown[1,2] that transistors exhibit *potential instability* within certain frequency ranges. The frequency range of potential instability is different for the three transistor configurations (common-emitter, -base and -collector).[3]

At frequencies where the transistor configuration is unconditionally stable (*i.e.*, where the transistor cannot become unstable, no matter what passive terminations are used), the maximum available power gain can be calculated.[1] However, at frequencies, where potential instability exists, the transistor may oscillate and the maximum power gain is infinite. Consequently, at such frequencies, the unqualified "maximum available power gain" is not a very useful concept. On the other hand, engineers engaged in the development of transistor circuitry do know very well that a practical measure for the maximum power gain realizable in a stable amplifier is indeed useful and very much needed. Furthermore, experience shows that such a maximum stable gain does actually exist.

Various attempts have been made to define a practical measure indicative of the maximum realizable power gain. For example, it has been shown that the transistor has a finite maximum gain if conjugately matched at its output, the termination at the input being either a pure resistance[4] or a resistance in combination with a reactance tuning out the reactive component of h_{11}.[5] It also has been thought that the "neutralized gain" may be a useful measure of stable amplifying capability and, besides other expressions, Mason's U function[6] has been suggested as a practical indication of attainable stable power gain.

These and other approximations for the maximum realizable stable power gain have the common advantage of presenting the practicing engineer with a measure useful as a reference. Their common disadvantage lies in the fact that the physical conditions under which these gain expressions can actually be realized are chosen essentially arbitrarily and are quite different from the situation most frequently occurring (and most desirable) in practice: the case of an unneutralized amplifier using impedance transforming ("matching") tuned circuits at both input and output ports.

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J. G. Linvill and L. G. Schimpf, "Design of tetrode transistor amplifiers," *Bell Syst. Tech. J.*, vol. 35, p. 813; July, 1956.

[2] A. P. Stern, C. A. Aldridge, and W. F. Chow, "Internal feedback and neutralization of transistor amplifiers," PROC. IRE, vol. 43, pp. 838–847; July, 1955.

[3] A. P. Stern, "Considerations on the Stability of Active Elements and Applications," 1956 IRE CONVENTION RECORD, Part 2, pp. 46–52.

[4] R. L. Pritchard, "High frequency power gain of junction transistors," PROC. IRE, vol. 43, pp. 1075–1085; September, 1955.

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[6] S. J. Mason, "Power gain in feedback amplifiers," IRE TRANS., vol. CT-1, pp. 20–25; June, 1954.

In order to obtain an expression for the maximum realizable stable power gain which is clean and acceptable from both practical and conceptual points of view, it seems desirable to tie in the maximum realizable power gain with a measure indicating the stability of the amplifier. If this is done, the maximum power gain is finite for stable amplifiers and can appear as a *function of the degree of stability* of the amplifier.

The purpose of this paper is to discuss the maximum power gain of transistor amplifiers using a measure of stability which appears to be both simple and practical. The following considerations can be applied directly to other active nonunilateral two-port elements.[7]

The Stability Factor "k"

The following calculations make use of the "y" matrix elements (the admittance parameters) of the transistor and external circuit elements are represented as admittances. This procedure is arbitrary; analogous calculations can be carried out using the "z" matrix elements and external impedances or the "h" (or "g") matrix elements and suitable combinations of admittances and impedances. It will be shown that these various representations have their respective advantages depending on the types of resonant circuits used in the tuned amplifier.

If y_{ij} are the admittance parameters of the transistor, one can write, separating real and imaginary components:

$$y_{11} = g_{11} + jb_{11} \tag{1}$$

$$y_{22} = g_{22} + jb_{22} \tag{2}$$

$$y_{12}y_{21} = M + jN. \tag{3}$$

The absolute value of the "internal loop gain" ($y_{12}y_{21}$) is

$$L = |y_{12}y_{21}| = \sqrt{M^2 + N^2}. \tag{4}$$

It has been shown[1-3] that if

$$L + M \geqq 2g_{11}g_{22} \tag{5}$$

the transistor *may* oscillate without external feedback, if properly terminated.

If the transistor is terminated by a generator admittance Y_G and a load admittance Y_L (Fig. 1), both Y_G

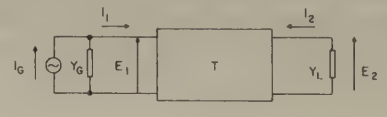


Fig. 1—Transistor with terminating admittances.

and Y_L may be complex:

$$Y_G = G_G + jB_G \tag{6}$$

$$Y_L = G_L + jB_L. \tag{7}$$

The transistor and the conductive components of the terminating admittances can be considered as constituting a new two terminal pair element C (Fig. 2). Applying

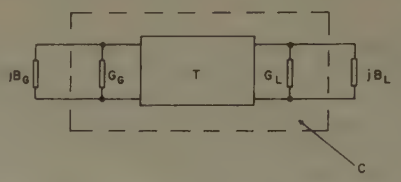


Fig. 2—Transistor and conductive terminating components forming composite network C.

inequality (5) to C, one finds the condition of potential instability:

$$L + M \geqq 2(g_{11} + G_G)(g_{22} + G_L). \tag{8}$$

Note that (8) does not imply actual instability: in order that the arrangement be actually unstable, C must be terminated by suitable susceptances B_G and B_L. However, in most tuned amplifiers, the terminating (or coupling) susceptances are variable and are actually varied when "tuning up" the amplifier. In arrangements having reasonably narrow band, the terminating susceptances will assume a wide range of values. Consequently, it can be assumed that, in most cases, during the tuneup procedure, B_G and B_L will assume values resulting in oscillation, provided that (8) is satisfied. Therefore, for many practical purposes, it can be stated that, if (8) is satisfied, the amplifier is not only *potentially unstable*, but is very likely to become *actually unstable*.

Unconditional stability can be achieved if

$$(g_{11} + G_G)(g_{22} + G_L) > (L + M)/2. \tag{9}$$

In other words, for stability, one requires

$$(g_{11} + G_G)(g_{22} + G_L) = k(L + M)/2 \tag{10}$$

where $k > 1$. The larger k, the more remote is the likelihood of instability. Consequently, k can be considered as a measure of stability and will be called *stability factor*.

For any individual transistor, whose parameters are known, stability can be achieved by chosing G_G and G_L such as to make k slightly larger than 1. However, considering that transistor parameters (*i.e.*, the y_{ij}) vary with transistor age, dc bias, temperature, etc., that transistors belonging to the same type have slightly different parameters and, finally, that certain variations in G_G and G_L must also be tolerated (especially if the terminations are other transistor amplifier stages), it is usually desirable to design the amplifier with k well in excess of unity in order to insure interchangeability of

[7] An approach similar to the one presented in this paper has been used independently by G. Bahrs in his doctoral thesis at Stanford University, Stanford, Calif.

components and stability under all reasonable conditions of operation. (Values of k up to 10 may be desirable, depending on the various tolerances involved.)

An infinite number of combinations of G_G and G_L correspond to the same value of k. Although the degree of stability of all these arrangements is the same, they may lead to different values of power gain. In the following section, the power gain will be maximized for a given value of k.

Analysis of a One-Stage Amplifier

The Power Gain

The transducer gain G_T is defined as the ratio of the power delivered to the load admittance Y_L to the available power of the generator having an admittance Y_G. The transducer gain is:

$$G_T = \frac{4\,|\,y_{21}\,|^2 G_G G_L}{|\,(y_{11}+Y_G)(y_{22}+Y_L)-y_{12}y_{21}\,|^2}. \tag{11}$$

Defining:

$$g_{11}+G_G=G_1, \tag{12}$$

$$g_{22}+G_L=G_2, \tag{13}$$

$$b_{11}+B_G=B_1, \tag{14}$$

$$b_{22}+B_L=B_2, \tag{15}$$

one finds for a given stability factor k:

$$G_1 = k(L+M)/2G_2. \tag{16}$$

Then, the transducer gain is:

$$GT=\frac{N}{D}=\frac{4\,|\,y_{21}\,|^2[k(L+M)/2G_2-g_{11}](G_2-g_{22})}{[B_1B_2-k(L+M)/2+M]^2} + [B_1G_2+B_2k(L+M)/2G_2-N]^2. \tag{17}$$

It is desired to find the value of G_2 which leads to maximum G_T for a given k. In order to find G_T as a function of G_2 alone, it is convenient to eliminate the two other variables B_1 and B_2. Since B_1 and B_2 occur only in the denominator D of (17), this can be done by determining the values of B_1 and B_2 which minimize the denominator. It should be remembered that, B_1 and B_2 representing susceptances, must be positive or negative *real* numbers.

The process of minimizing D in (17) can be simplified by a change of variables. One defines

$$y_1 = B_1G_2 + B_2k(L+M)/2G_2 \tag{18}$$

$$y_2 = B_1B_2. \tag{19}$$

D can then be written:

$$D = (y_2-A)^2+(y_1-N)^2 \tag{20}$$

where

$$A = k(L+M)/2 - M. \tag{21}$$

Note that for $k>1$, A is always positive. B_1 and B_2 can be expressed in terms of the new variables y_1 and y_2:

$$B_1 = (y_1+\sqrt{\Delta})/2G_2 \tag{22}$$

$$B_2 = (y_1-\sqrt{\Delta})G_2/k(L+M) \tag{23}$$

where

$$\Delta = y_1^2 - 2k(L+M)y_2. \tag{24}$$

Since G_2 and $k(L+M)$ are always real numbers, B_1 and B_2 will be real, whenever

$$\Delta \geqq 0. \tag{25}$$

In the y_1-y_2 plane, the curve $\Delta=0$ separates the region of real values of B_1 and B_2 from the region in which these quantities are complex. The equation

$$\Delta = y_1^2 - 2k(L+M)y_2 = 0 \tag{26}$$

is that of a parabola in the y_1-y_2 plane (Fig. 3), the

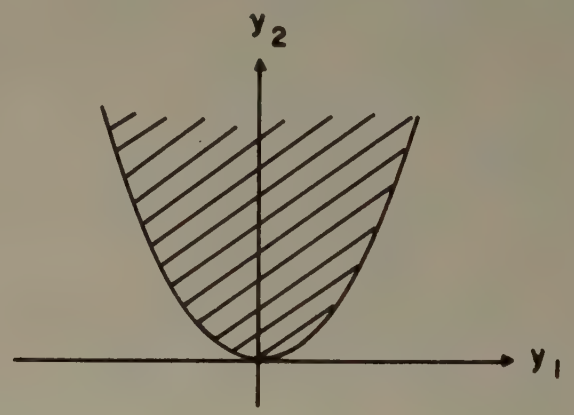


Fig. 3—Parabola separating region of complex B_1 and B_2 (shaded) from region in which B_1 and B_2 are real.

shaded area "inside" the parabola representing the region of complex values of B_1 and B_2 and the area "external" to the parabola being the region of real values of B_1 and B_2.

In a three-dimensional coordinate system with axes D, y_1 and y_2, (20) represents a paraboloid of revolution, whose axis is perpendicular to the y_1-y_2 plane and intersects this plane at the point $Q(N, A)$. In the same space, (26) is that of a parabolic cylinder. [Fig. 4 shows the parabola (26) and the projection of "constant D circles" on the y_1-y_2 plane.] The "interior" of this cylinder is the space within which D cannot lie if B_1 and B_2 are real and one is interested to determine the minimum value of D "outside" the parabolic "wall." [The vertex Q of the paraboloid having coordinates (N, A), where A is always positive for $k>1$, will be "inside" the parabolic cylinder, since it corresponds to infinite gain, which of course, is excluded, in view of the assumptions regarding stability.]

An analysis of the geometrical situation shows that the minimum of D (*i.e.*, the maximum of the gain) will

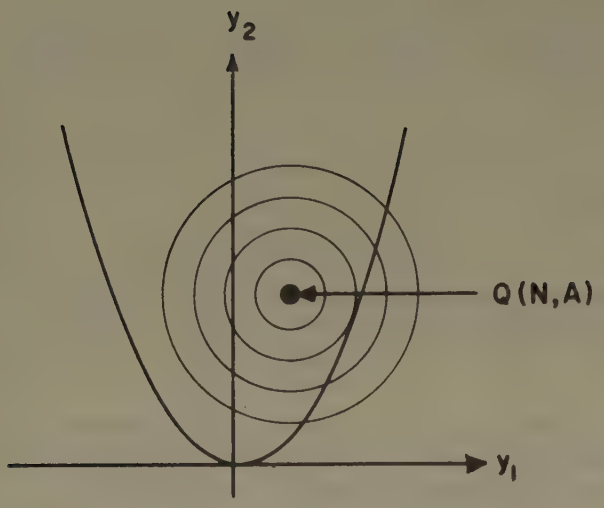


Fig. 4—Parabola (26) and projections of constant D circles on the y_1-y_2 plane.

occur along the intersection of the paraboloid with the parabolic cylinder. In Fig. 4, circles with increasing diameter correspond to increasing values of the denominator D (and, consequently, to decreasing values of the gain). The minimum realizable value of D with real B_1 and B_2 occurs where a circle is tangent to the parabola, *i.e.*, at a point common to both paraboloid and parabolic cylinder. Geometrical considerations also show that two cases are possible:

1) If the location of the point $Q(N, A)$ is such as shown in Fig. 5(a) (with only one point P_0 at which a circle corresponding to constant D is tangent to the parabola), the intersection of the paraboloid and the parabolic cylinder has *one* minimum at point P_0 corresponding to $D=D_0$.

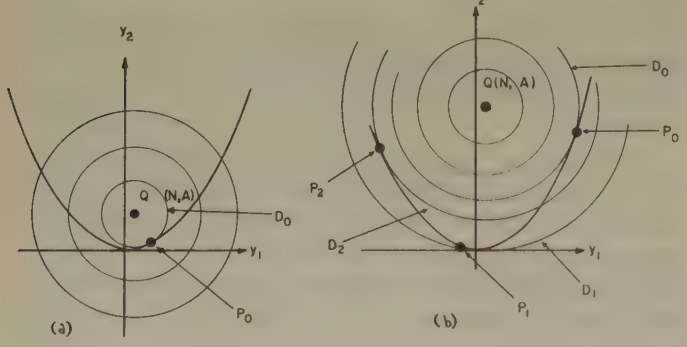


Fig. 5—Situations leading to one minimum (a) and three extrema (b) respectively.

2) If there are three points at which "constant D circles" are tangent to the parabola, there is a minimum at P_0 corresponding to a low value D_0 of D. There is a second minimum at P_2 corresponding to the higher level D_2 of D and there is a maximum at P_1 corresponding to an even higher level D_1 of D. In this case the maximum gain is given by the smaller minimum occurring at P_0.

These qualitative considerations can be put into quantitative form. Since D_0 occurs along the intersection of the paraboloid with the parabolic cylinder, one must determine the minimum of (20) with condition (26).

Defining the variable z as

$$z = y_1/\sqrt{k(L+M)} \tag{27}$$

D can be written:

$$D = z^4/4 + [k(L+M)+2M]z^2/2 - 2N\sqrt{k(L+M)}z + A^2 + N^2. \tag{28}$$

The minimum of D can be found by setting

$$0 = dD/dz = z^3 + [k(L+M)+2M]z - 2N\sqrt{k(L+M)}. \tag{29}$$

As expected from the foregoing qualitative analysis, (29) leads to two possibilities:

1) (29) has one real root z_0, the other two being conjugate complex. In this case z_0 corresponds to D_0.

2) (29) has three real roots. Two roots (z_0 and z_2) represent minima of D, z_0 corresponding to the smaller minimum, while the third root (z_1) is a maximum.

In either case, z_0 leads to the maximum realizable gain. Substituting z_0 into (28), the minimum value D_0 of D is found. Note that, since both z_0 and D are functions of k and $(y_{12}y_{21})$ only, D_0 depends only on k and $(y_{12}y_{21})$ and is independent of other transistor parameters and of conductive terminations.

Assuming now that D_0 is known, the gain (maximized with regard to B_1 and B_2) can be written:

$$G_T = (4|\,y_{21}\,|^2/D_0)[k(L+M)/2G_2 - g_{11}](G_2 - g_{22}). \tag{30}$$

Generator and load conductances are assumed to be positive and one must have $G_1 > g_{11}$ and $G_2 > g_{22}$. In other words:

$$k(L+M)/2g_{11} > G_2 > g_{22}. \tag{31}$$

Setting $dG_T/dG_2 = 0$, one finds that for maximum realizable power gain:

$$G_2 = \sqrt{k(L+M)/2}\sqrt{g_{22}/g_{11}} \tag{32}$$

and, using (16):

$$G_1 = \sqrt{k(L+M)/2}\sqrt{g_{11}/g_{22}}\,. \tag{33}$$

Substituting these expressions into (30), the maximum realizable gain, corresponding to the stability factor k, is found:

$$G_{\max k} = (4|\,y_{21}\,|^2/D_0)[\sqrt{k(L+M)/2} - \sqrt{g_{11}g_{22}}]^2. \tag{34}$$

Eq. (34) expresses the maximum power gain realizable with a given stability factor k. As k increases, $G_{\max,k}$ decreases. Consequently, one can say that increased stability can be achieved by sacrificing gain. It is, how-

ever, important to know, that moderate gain does not necessarily imply improved stability: k is determined by the product (G_1G_2) and this product can be chosen such that while k is small (close to instability), the gain is also small due to a disadvantageous ratio (G_1/G_2). In this case gain is sacrificed without improvement in stability.

From (32) and (33) the required values of the terminating conductances are found:

$$G_G = G_1 - g_{11}$$
$$= g_{11}[\sqrt{k(L+M)/2}/\sqrt{g_{11}g_{22}} - 1] \quad (35)$$
$$G_L = G_2 - g_{22}$$
$$= g_{22}[\sqrt{k(L+M)/2}/\sqrt{g_{11}g_{22}} - 1].^8 \quad (36)$$

The required values of the susceptances can be determined, using (22), (23), and (27):

$$B_1 = B_G + b_{11} = G_1 z_0/\sqrt{k(L+M)} \quad (37)$$
$$= z_0\sqrt{k(L+M)}/2G_2$$
$$B_2 = B_L + b_{22} = G_2 z_0/\sqrt{k(L+M)} \quad (38)$$

where G_1 and G_2 are given by (32) and (33). Eqs. (37) and (38) show that B_1 and B_2 have identical sign (that of z_0). This, of course, is not necessarily true for B_G and B_L.

Bandwidth Limitations

The preceding computations were carried out without regard to possible selectivity requirements. In reality, however, when designing a tuned amplifier, the bandwidth requirements are very important and, usually, the following problem must be solved: "design a stable amplifier with given center frequency and bandwidth and obtain as high gain as possible."

Simple considerations show that realizing the maximum gain imposes certain limitations on the bandwidth and, on the other hand, requiring a certain bandwidth imposes certain restrictions on the gain. These limitations belong to two categories:

1) Limitations due to the transistor (device limitations) and
2) Limitations due to external circuit elements.

Some aspects of the gain vs bandwidth relationship can be explained by considering the transistor terminated by synchronous single tuned circuits. Since the y parameters were used in the preceding calculations, it is convenient to use parallel tuned circuits, as shown in Fig. 6. It is assumed that the transistor parameters

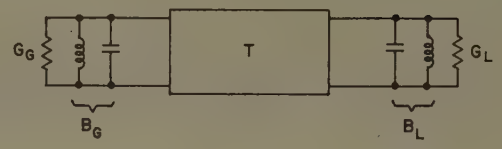


Fig. 6—Transistor with parallel tuned terminations

are frequency independent throughout the frequency band of interest.

The device limitations can be understood *qualitatively* in the following manner. The values of G_G and G_L leading to maximum gain are given by (35) and (36). Maximum gain will be realized only if the values of B_1 and B_2 are those given by (37) and (38). Considering now, say, the output selectivity one may assume, for example, that the required value of $B_L(=B_2-b_{22})$ is positive. This implies that the load susceptance must be capacitive and since the load consists of L_L and C_L in parallel, the required value of B_L can be realized only if $\omega_0 C_L > (B_2-b_{22})$, ω_0 being the center frequency of the amplifier. Consequently, for maximum gain the tuned circuit must contain a capacitance C_L exceeding the value of $(B_2-b_{22})/\omega_0$. However, this and the possible capacitive component of the transistor driving point admittance impose an upper limit on L_L. This results in an upper limit of bandwidth realizable with the maximum gain given by (34). If larger bandwidth is required, a smaller capacitance C_L will be used, implying that the denominator of the gain expression in (17) will not be D_0 but larger and, therefore, the gain will be reduced. Similarly, if B_L is required to be negative, meaning an inductive load susceptance, there is a maximum admissible value of L_L. This again imposes an upper limit on the bandwidth realizable with the calculated maximum gain. Analogous considerations do apply, of course, to the input selectivity.

The bandwidth limitations resulting from device properties are not important in the case of most amplifiers having reasonably narrow bandwidth. Their analytical treatment is complicated and will not be dealt with here.

The limitations imposed by the required bandwidth upon the realizable gain due to external circuit elements are caused by the finite "Q" of practical inductances and can be calculated.

In the circuit of Fig. 7, g_{x1} and g_{x2} represent the

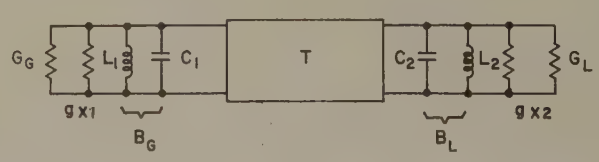


Fig. 7—Transistor with tuned circuits having finite "Q."

equivalent parallel loss conductances of inductances L_1 and L_2. Q_0 being the "unloaded Q" of the inductances and assuming that $Q_{01}=Q_{02}=Q_0$, one has:

[8] Eqs. (35) and (36) show that G_G and G_L will be positive if the bracketed expressions on the right hand side of these equations are positive, *i.e.*, if the stability factor k of the terminated amplifier exceeds the stability factor k_0 of the unloaded amplifier. If the unloaded amplifier is stable in itself, for positive terminations, one must have $k>k_0$.

$$Q_0 = 1/\omega_0 L_1 g_{x1} = 1/\omega_0 L_2 g_{x2}. \quad (39)$$

The transistor is still treated in terms of its y parameters but the loss conductances g_{x1} and g_{x2} are considered to be parts of g_{11} and g_{22} respectively. One has:

$$g_{11} = g_{11}' + g_{x1} \quad (40)$$

$$g_{22} = g_{22}' + g_{x2} \quad (41)$$

where g_{11}' and g_{22}' are the short circuit input and output conductances of the transistor itself. The transducer gain is:

$$G_T = (4|y_{21}|^2/D_0)[k(L+M)/2G_2 - g_{11}' - g_{x1}](G_2 - g_{22}' - g_{x2}). \quad (42)$$

Assuming that the tuned circuits at the input and the output are synchronously tuned but may have different fractional bandwidths $B^{(1)}$ and $B^{(2)}$ ($B = \Delta\omega/\omega_0$, where $\Delta\omega$ is the 3-db bandwidth):

$$B^{(1)} = (G_G + G_{in})/Q_0 g_{x1} \quad (43)$$

$$B^{(2)} = (G_L + G_{out})/Q_0 g_{x2}. \quad (44)$$

G_{in} and G_{out} are the conductive components of the transistor driving point admittances when the transistor is terminated.

$$G_{out} = g_{22} - (MG_1 + NB_1)/(G_1^2 + B_1^2). \quad (45)$$

Using (37) and defining:

$$W = \frac{M + z_0 N/\sqrt{k(L+M)}}{1 + z_0^2/[k(L+M)]} \quad (46)$$

one finds:

$$G_{out} = g_{22} - [2W/k(L+M)]G_2. \quad (47)$$

Similarly:

$$G_{in} = g_{11} - (MG_2 + NB_2)/(G_2^2 + B_2^2). \quad (48)$$

Using (38), one finds:

$$G_{in} = g_{11} - W/G_2. \quad (49)$$

Eqs. (48) and (49) can be substituted into (43) and (44), yielding:

$$B^{(1)} = [k(L+M)/2G_2 Q_0 g_{x1}][1 - 2W/k(L+M)] \quad (50)$$

$$B^{(2)} = [G_2/Q_0 g_{x2}][1 - 2W/k(L+M)]. \quad (51)$$

Substituting g_{x1} and g_{x2} from (50) and (51) in the gain expression (42), G_T is obtained as a function of G_2 alone. Equating (dG_T/dG_2) to zero, the value of G_2 leading to maximum gain is found:

$$G_2 = \sqrt{k(L+M)/2}\sqrt{(1 - P/Q_0 B^{(1)})/(1 - P/Q_0 B^{(2)})} \cdot \sqrt{g_{22}'/g_{11}'}. \quad (52)$$

The corresponding value of G_1 is:

$$G_1 = \sqrt{k(L+M)/2}\sqrt{(1 - P/Q_0 B^{(2)})/(1 - P/Q_0 B^{(1)})} \cdot \sqrt{g_{11}'/g_{22}'}. \quad (53)$$

where:

$$P = 1 - 2W/k(L+M). \quad (54)$$

Substituting G_2 in expression (42), the maximum realizable gain is:

$$G_{max,k} = (4|y_{21}|^2/D_0)[\sqrt{(k/2)(L+M)} \cdot \sqrt{(1 - P/Q_0 B^{(1)})(1 - P/Q_0 B^{(2)})} - \sqrt{g_{11}' g_{22}'}]^2. \quad (55)$$

If $B^{(1)} = B^{(2)} = B$, (55) becomes:

$$G_{max,k} = (4|y_{21}|^2/D_0)[(1 - P/Q_0 B)\sqrt{k(L+M)/2} - \sqrt{g_{11}' g_{22}'}]^2. \quad (56)$$

Eqs. (55) and (56) show that the finite Q of external circuit elements reduces the maximum realizable gain at *small bandwidths*, whereas the device limitations have been shown to reduce the maximum realizable gain at large bandwidths.

Multistage Amplifiers

The method used in the previous sections to determine the maximum realizable transducer gain maintaining a given degree of stability can also be applied to multistage amplifiers. In such amplifiers, interstage coupling is usually performed by "impedance matching"[9] tuned transformers. The problem is to determine the turns ratio m of the transformers and the conductances terminating the amplifier at its input (G_G of the first stage) and its output (G_L of the last stage) terminal pairs. When carrying out such calculations for multistage amplifiers, the following points should be observed:

1) The expression to be maximized is the transducer gain of the amplifier. The transducer gain of the multistage amplifier is, however, *not* the product of the transducer gains of the individual stages, but is the transducer gain of the first stage multiplied by the product of the actual power gains of the remaining stages.
2) The interstage transformer having turns ratio m transforms impedances in both directions. Therefore, since individual stages are terminated by the transformed driving point admittances of adjoining stages, load and source admittances of individual stages cannot be chosen independently. The condition for maximum over-all gain of the amplifier, all stages being operated with a certain de-

[9] The word "matching" is inappropriately used in an amplifier with prescribed stability factor k, since, in order to insure stability, the stages are deliberately mismatched.

sired stability factor k, does not imply that the individual stages are operated for maximum individual gain. Consequently, the maximum over-all gain of an n-stage amplifier, all of whose stages have the stability factor k, is less than n times the maximum gain realizable with a single stage having the same degree of stability.

It should be mentioned that, already in the case of two-stage amplifiers (the analysis of which is outlined in Appendix II) the algebraic and numerical evaluation of the equations becomes exceedingly involved. The complete evaluation of such or more complicated cases (for example, that of iterative stages) should be handled with the aid of appropriate computing machinery.

The Use of Different Matrix Representations

In the preceding sections, the discussion was based on the use of the admittance parameters. Since condition (5) can be stated in analogous form in terms of the "z," "h," and "g" parameters, all calculations could be carried out in terms of these other matrix representations. In fact, the calculations could have been carried out in terms of generalized "k" parameters, provided that the generator immittance is given the dimension of k_{11} and load immittance the dimension of k_{22}.

However, the different matrix representations have their respective advantages, depending on the nature of the terminating (or interstage coupling) tuned circuits. The following sets of parameters should be used with different types of tuned circuits:

1) y parameters with parallel tuned circuits at input and output (or parallel-parallel interstage networks)—see Fig. 8(a).
2) z parameters with series tuned circuits at input and output (or series-series tuned interstage networks)—see Fig. 8(b).
3) h parameters with series tuned circuit at the input and parallel tuned circuit at the output (or parallel-series tuned interstage networks)—see Fig. 8(c).
4) g parameters with parallel tuned circuit at the input and series tuned circuit at the output (or series-parallel tuned interstage networks)—see Fig. 8(d).

With transistors, cases 1) and 3) have practical importance. Cases 2) and 4) are almost never used because the transistor driving point immittances would lead to inconvenient values of inductances and capacitances.

Some numerical calculations are carried out in Appendix I, using the h parameters.

Conclusion

It has been shown that using an appropriately defined "stability factor" k, the "maximum gain" of a transistor amplifier is a meaningful concept even at frequencies where the transistor exhibits potential instability. The maximum gain corresponding to a given stability factor k has been computed for a one-stage amplifier having tuned generator and load admittances. The gain limitations due to bandwidth requirements have also been discussed for this case.

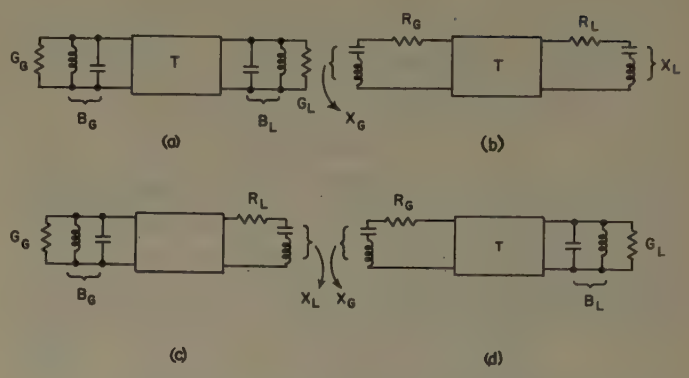


Fig. 8—Various tuned amplifier configurations.

Appendix I

Some Numerical Examples

We consider a transistor having the following nominal device parameters:

Low-frequency common-base short circuit current amplification: $a_0 = 0.99$.
Cutoff frequency of the common-base short circuit current amplification: $\omega_a/2\pi = 10$ mc.
Collector capacitance: $C_c = 10$ uuf.
Base spreading resistance: $r_b' = 100$ ohms.
Emitter diffusion resistance (at 1-ma emitter current): $r_e = 25$ ohms.

We are interested in the maximum power gain realizable with this transistor in *common emitter* configuration with various given values of the stability factor k. The operating frequency is assumed to be $\omega/2\pi = 0.5$ mc and, consequently: $\rho = \omega/\omega_a = 0.05$.

The circuit used is shown in Fig. 9 and calls for the use of the h parameters. Using the approximate equivalent circuit of Fig. 10 the parameters of interest can be calculated.

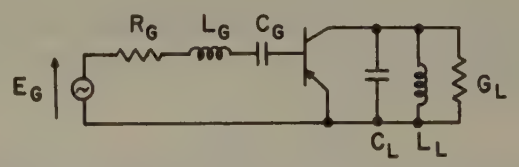


Fig. 9—Common emitter circuit with series tuned input and parallel tuned output.

The real component of h_{11} is:

$$r_{11} \cong r_b' + r_e(1 - a_0)/\rho^2 \cong 200 \text{ ohms.} \qquad (57)$$

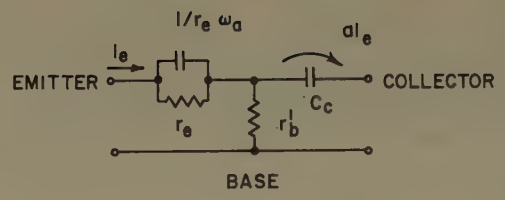


Fig. 10—Approximate equivalent circuit of a junction transistor.

The real component of h_{22} is:

$$g_{22} \cong \omega_a C_c \cong 6 \times 10^{-4} \text{ mhos.} \tag{58}$$

The "internal loop amplification" ($h_{12}h_{21}$) is:

$$h_{12}h_{21} \cong [\omega_a C_c r_e + j\omega_a C_c r_e(1 - a_0)/\rho](1/j\rho) \tag{59}$$
$$\cong 0.06 - j\,0.3.$$

The device is potentially unstable, since

$$[\,|\,h_{12}h_{21}\,| + \text{Re}\,(h_{12}h_{21})]/2 \cong 0.19 > r_{11}g_{22} \cong 0.12. \tag{60}$$

The choice of k depends on the admissible tolerances in device parameters and in the load. For the *nominal* parameters and corresponding terminations we want to have

$$(R_g + r_{11})(G_L + g_{22}) = k[\,|\,h_{12}h_{21}\,| + \text{Re}\,(h_{12}h_{21})]/2. \tag{61}$$

Since Im $(h_{12}h_{21}) \gg$ Re $(h_{12}h_{21})$, the right-hand side of (61) will vary like [see (59)]

$$\text{Im}\,(h_{12}h_{21}) \cong \omega_a{}^2 C_c r_e/\omega. \tag{62}$$

We may, for example, assume that ω_a, C_c, r_e will each have a tolerance (in the upper direction) of 3 per cent. Furthermore, we may assume that the two factors in the left-hand side of (61) will vary by no more than 3 per cent each in the lower direction (these tolerances are too small to be realistic and they are also inexact, since both r_{11} and g_{22} are functions of the device parameters). We would then require $k \cong (1.03)^6 \cong 1.2$. Computing the corresponding maximum gain, we find

$$G_{\max,1.2} \cong 36 \text{ db.}$$

By increasing the tolerances to, say, +10 per cent in each factor on the right-hand side of (62) and to −10 per cent on the left-hand side of (61), we require $k \cong 1.7$, leading to

$$G_{\max,1.7} \cong 33 \text{ db.}$$

By increasing the tolerances even further, to +30 per cent in ω_a and r_e, +50 per cent in C_c, −10 per cent in $(G_G + g_{11})$ and $(G_L + g_{22})$, we require $k \cong 4$. This leads to

$$G_{\max,4} \cong 30 \text{ db.}$$

A further increase in tolerances may require $k = 8$ and leads to

$$G_{\max,8} \cong 28 \text{ db.}$$

The example shows that the tolerances in device parameters (ω_a, C_c), emitter current (r_e is principally a function of the emitter current) and terminations (G_G and G_L) have considerable influence on the maximum realizable stable gain.

Similar calculations can be carried out for the *common base* stage. Here we have:

$$r_{11} \cong r_e \cong 25 \text{ ohms} \tag{63}$$
$$g_{22} \cong \omega^2 C_c{}^2 r_b' \cong 10^{-7} \text{ mhos} \tag{64}$$
$$h_{12}h_{21} \cong -j\omega C_c r_b' a_0 \cong 3.10^{-3}. \tag{65}$$

The device is potentially unstable, since:

$$[\,|\,h_{12}h_{21}\,| + \text{Re}\,(h_{12}h_{21})]/2 \cong 15 \times 10^{-4}$$
$$r_{11}g_{22} \cong 25 \times 10^{-7}.$$

Calculating the maximum gain for the same values of k as in the common emitter case, we find:

$k = 1.2$ $\quad G_{\max,1.2} \cong 44$ db

$k = 1.7$ $\quad G_{\max,1.7} \cong 36$ db

$k = 4.0$ $\quad G_{\max,4} \cong 28$ db

$k = 8.0$ $\quad G_{\max,8} \cong 25$ db.

Note that in the common base case, these values of k correspond to *different tolerances* in the device parameters than in the common emitter case. With the particular set of device parameters chosen, the common base gain is higher for low (impractical) values of k, whereas at higher values of k, the common emitter gain is superior.

Note furthermore, that for a different circuit (for example, if parallel tuned circuits are used at both input and output, where the y parameters should be employed instead of the h parameters used in the above example), different values of k will correspond to the same permissible tolerances in the device parameters and different values of maximum gain may be realized.

Appendix II

Outline of the Analysis of a Two-Stage Amplifier

The schematic circuit of an amplifier consisting of two stages T_1 and T_2 is shown in Fig. 11.

We designate by:

P_G = the power available from source Y_G.

P_L = the power delivered to load Y_L.

P_{i2} = the power delivered by T_1 to T_2.

$G_{T,\text{total}}$ = the transducer gain of the two-stage amplifier.

G_{T1} = the transducer gain of T_1.

G_{P2} = the actual power gain of T_2 (= power delivered to Y_L divided by input power of T_2).

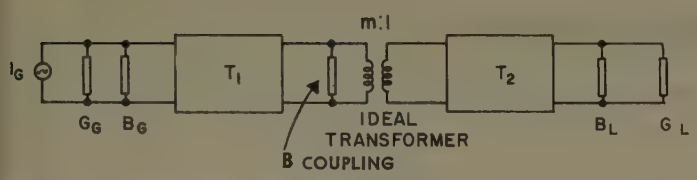


Fig. 11—Two stage amplifier with interstage impedance transformation (in practice the ideal transformer would, of course, be part of the coupling susceptance).

Then:

$$G_{T,\text{total}} = \frac{P_L}{P_G} = \frac{P_{i2}}{P_G}\cdot\frac{P_L}{P_{i2}} = G_{T1}\cdot G_{P2}. \tag{66}$$

Defining G_1 and G_2 in the sense used throughout the body of this paper and indicating by a second subscript whether the quantity considered belongs to T_1 or T_2, one has according to (10) and (30):

$$G_{T1} = \frac{4|y_{21}|^2}{D_0}(G_{11} - g_{11})\left[\frac{k(L+M)}{2G_{11}} - g_{22}\right]. \tag{67}$$

The power gain of T_2 is:

$$G_{P2} = \frac{|y_{21}|^2(G_{22} - g_{22})}{g_{11}[G_{22}^2 + B_{22}^2] - MG_{22} - NB_{22}}. \tag{68}$$

For any given value of G_{22}, G_{P2} will be maximum if

$$B_{22} = N/2g_{11}. \tag{69}$$

Substituting (69) into (68), G_{P2} can then be written:

$$G_{P2} = \frac{4g_{11}|y_{21}|^2(G_{22} - g_{22})}{(2g_{11}G_{22} - M)^2 - L^2}. \tag{70}$$

The transducer gain of the complete amplifier is:

$$G_{T,\text{total}} = \frac{16g_{11}|y_{21}|^4}{D_0}(G_{11} - g_{11})\left[\frac{k(L+M)}{2G_{11}} - g_{22}\right]\cdot\frac{G_{22} - g_{22}}{(2g_{11}G_{22} - M)^2 - L^2}. \tag{71}$$

The load admittance of T_1 is $(1/m^2)$ times the input admittance of T_2 and the generator admittance of T_2 is m^2 times the output admittance of T_1. Furthermore, the same stability factor is required for both stages and (10) applies to both stages. In view of (69) and (46) one can write:

$$G_{21} = \frac{k(L+M)}{2G_{11}} = g_{22} + \frac{1}{m^2}\left(g_{11} - \frac{MG_{22} + N^2/2g_{11}}{G_{22}^2 + N^2/4g_{11}^2}\right) \tag{72}$$

and

$$G_{12} = \frac{k(L+M)}{2G_{22}} = g_{11} + m^2\left(g_{22} - \frac{W}{G_{11}}\right). \tag{73}$$

These two equations establish relationships between $G_L(=G_{22}-g_{22})$, $G_G(=G_{11}-g_{11})$ and m. m can be eliminated by multiplying (72) by (73). One finds:

$$\left[\frac{k(L+M)}{2G_{22}} - g_{11}\right]\left[\frac{k(L+M)}{2G_{11}} - g_{22}\right] = \left(g_{22} - \frac{W}{G_{11}}\right)\left(g_{11} - \frac{MG_{22} + N^2/2g_{11}}{G_{22}^2 + N^2/4g_{11}^2}\right). \tag{74}$$

Eq. (74) relates G_{11} to G_{22} (or G_L to G_G). One of these quantities can be expressed as a function of the other and substituted into the gain expression (71). Then, in principle, the maximum over-all transducer gain can be determined. It is, however, obvious that this procedure involves computational difficulties due to the complicated nature of the resulting gain expression.

Acknowledgment

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Ferrod Radiator System*

F. REGGIA†, ASSOCIATE, IRE, E. G. SPENCER†, R. D. HATCHER†, AND J. E. TOMPKINS†

Summary—**Commercially available ferrites with low dielectric and magnetic losses at microwave frequencies have brought about the development of ferrod radiator systems for 3-cm wavelength. These ferrites are, in general, characterized by high dielectric constants (approximately 13) and initial permeabilities slightly less than unity. The use of these ferrimagnetic materials as ferrite rod (ferrod) radiators considerably reduces the physical size of microwave antenna systems.**

The high dielectric constant of the ferrite allows the diameter of the radiating elements of circular cross section to be approximately ¼ inch for 3-cm wavelength use. This makes possible magnetic coupling of the ferrod radiator from resonant cavities or from the narrow side of standard rectangular waveguides to obtain various types of linear arrays. A short feeding section (5/16 inch long) is used to support and lock the position of the ferrod. This device simplifies adjustments and reduces the mechanical tolerances necessary for the ferrod radiators.

Microwave ferrites are also characterized by a tensor permeability[1] which changes with applied magnetic field. This phenomenon is used to change the magnetic properties of the ferrod radiator to obtain electrical switching, scanning, lobing, changes in polarization, and amplitude or phase modulation of the radiated energy.

Phase shifters, switches, and circulators, which consist of short sections of ferrite-filled cylindrical waveguide, have also been developed for use with the ferrod radiator system.

Introduction

THE BASIC IDEAS of radiating short wavelength radio waves from dielectric media date back to the work done by Lord Rayleigh[2] in 1895. These ideas consist of shaping a length of dielectric material to control the phase and amplitude of the radiated energy.

Essentially, this is what was done to the ferrods which were used as radiating elements of 3-cm wavelength antenna systems developed by this laboratory.

An exact analysis of the operation of these ferrod radiators involves the solution of Maxwell's equations, subject to all the boundary conditions and parameters describing the ferrod. Its mathematical complexity is beyond the scope of this paper. For most engineering applications, however, a satisfactory explanation of its operation can be obtained by establishing analogies with array theory and with existing theories of transmission through uniform dielectric rods of circular cross section.

A good treatment of the theory of electromagnetic wave propagation along dielectric rods is given by Kiely[3] and McKinney.[4] These two surveys have been of particular help in determining the parameters necessary for obtaining good radiation characteristics. They also contain complete bibliographies of the literature available on dielectric-rod radiators.

Treatments of electromagnetic wave propagation in magnetically anisotropic media are given by Kales[5] and Gintsburg.[6] A similar treatment with the addition of graphical solutions of the transcendental equations involved in certain cases is given by Suhl and Walker.[7] Wave propagation in an infinite, magnetized ferrod is also being studied at this laboratory.

Ferrod Radiator System

A basic ferrod antenna system for 3-cm wavelength is shown in Fig. 1. It consists of a ferrite radiating element, a low current modulating coil, a short section of cylindrical waveguide for supporting the ferrod, a simple wire mode filter, and a short section of rectangular waveguide used to excite the ferrod radiator. The length of the entire system is approximately 5 inches.

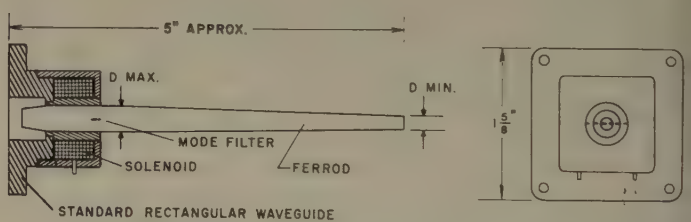


Fig. 1—Ferrod radiator system for 3-cm wavelength.

The radiating element used is a commercially available low-loss ferrite[8] which is properly shaped to give maximum radiation along its axis and minimum radiated power in the side lobes. The total length of the ferrod is 4.5 inches, and its diameter is 0.25 inch.

The ferrite-filled section of waveguide has an inside diameter of ¼ inch, and is approximately ¾ inch long.

* Original manuscript received by the IRE, December 7, 1956.
† Diamond Ordnance Fuze Labs., Washington, D. C.

[1] E. G. Spencer, R. C. LeCraw, and F. Reggia, "Measurement of microwave dielectric constants and tensor permeabilities of ferrite spheres," IRE PROC., vol. 44, pp. 790–800; June, 1956.

[2] Lord Rayleigh, "On the passage of electrical waves through tubes or the vibrations of dielectric cylinder," *Phil. Mag.*, vol. 43, pp. 125–132; February, 1897.

[3] D. G. Kiely, "Dielectric Aerials (Methuen's Monograph)," John Wiley and Sons, Inc., New York, N. Y.; 1953.

[4] C. M. McKinney, Jr., "Dielectric Waveguides and Radiators," Bumblebee Rep. No. 138, Defense Res. Lab., Univ. of Texas, Austin, Texas; 1950.

[5] M. L. Kales, "Modes in waveguides containing ferrites," *J. Appl. Phys.*, vol. 24, pp. 604–608; May, 1953.

[6] M. A. Gintsburg, "On waves in a gyrotropic medium," *C. R. Acad. Sci. (URSS)*, vol. 18; 1954. For English translation see Columbia Technical Translations No. 4, vol. 18, pp. 136–154; 1950.

[7] H. Suhl and L. R. Walker, *Bell Sys. Tech. J.*, vol. 33, pp. 579, 939, and 1133; 1954.

[8] General Ceramics R-1 Ferrite. A complete description of its microwave properties is given by Spencer, LeCraw, and Reggia, *op. cit.* See also R. C. LeCraw and E. G. Spencer, "Tensor permeabilities of ferrites below magnetic saturation," 1956 IRE CONVENTION RECORD, Part 5, pp. 66–74.

The mode filter, 0.020 inch thick and approximately 0.060 inch wide, goes through the ferrite and makes electrical contact to both sides of the circular waveguide. The low current solenoid,[9] 9/16 inch wide and $1\frac{3}{8}$ inch in diameter, required about 10 ma to operate. These three components make up the "ferrite mode switch" or modulating section of the system.

Operation of the mode switch depends upon the ferromagnetic Faraday effect[10] of the ferrite which causes a rotation of the plane of polarization of the microwave energy incident upon the mode filter when a longitudinal magnetic field is applied. When the polarization of the incident wave is perpendicular to the length of the mode filter, the wave propagates essentially unchanged. Rotating the polarization parallel to the length of the mode filter short-circuits the electric field, thus rejecting the microwave energy incident upon it. Greater than 20 db switching is obtained with this modulation section with control currents of 10 ma ($H_0 \approx 40$ oersteds).

Modulating frequencies in the kilocycle range have been used with the system shown in Fig. 1. It is possible to extend this frequency range up to a few megacycles by techniques reported by R. C. LeCraw[11] of this laboratory.

Design Data

Kiely[3] has shown the radiation pattern of a uniform dielectric rod of circular cross section excited in the HE_{11} mode to be given approximately by

$$E_\theta = \frac{(K-1)\sin\frac{\pi L}{\lambda_0}(K-\cos\theta)}{(K-\cos\theta)\sin\frac{\pi L}{\lambda_0}(K-1)}\cos\left(\frac{\pi d}{\lambda_0}\sin\theta\right)$$

where

E_θ = normalized electric field intensity
θ = angle between the axis of the dielectric rod and the position where the electric field is being determined
λ_0 = free space wavelength
λ = wavelength in an infinite medium of the dielectric
L = length of the dielectric rod
d = diameter of the dielectric rod.

The value of $K = \lambda_0/\lambda$ which gave optimum radiation characteristics was determined analytically to be 1.1, assuming no standing waves exist along the rod. To make this assumption valid, it was necessary to taper the rod to match the free space impedance. The calculated value of d_{max} for the tapered rod (see Fig. 1) was found to be $\lambda_0/\sqrt{\pi(\epsilon-1)}$, and the value of d_{min} was found to be 0.63 d_{max}. The magnetic permeability μ was assumed to be unity in this analysis.

The cutoff frequency (f_c) of a dielectric-filled waveguide of circular cross section operating in the TE_{11} mode is given by $f = 0.293\ c/a\sqrt{\mu\epsilon}$ where

c = velocity of light
a = radius of circular waveguide.

Using a ferrite with a relative dielectric constant ϵ of 13.6 and a permeability μ of 0.76 as the dielectric medium requires that a diameter no smaller than 0.240 inch be used for d_{max} in the 9–10 kmc frequency range. This is slightly larger than the diameter obtained from Kiely's equation. Using this value for d_{max}, the value of d_{min} was found to be 0.152 inch. Other parameters of the ferrod radiator were determined experimentally, such as the length of the taper which is a function of the ferrod length and the length of the feeding section.

A comparison between the calculated and measured values of the radiation pattern resulted in only approximate agreement. The largest discrepancies occurred in the amplitude and position of the side lobes. This is not surprising since existing theories are themselves only approximate. Also, because of the high dielectric constant of the ferrod, it is possible that some other mode may be excited.

The small diameter required for the ferrod radiator at 3-cm wavelength makes possible direct coupling from the narrow side of a standard rectangular waveguide or from a small resonant cavity. This simplifies the construction of various types of arrays for obtaining radiation patterns with more narrow beam widths.

A single ferrod radiator, properly shaped for optimum radiation characteristics, is shown in Fig. 2. It is coupled from the end of a rectangular waveguide (1.0×0.5 inch) by a small locking device, also shown in the foreground.

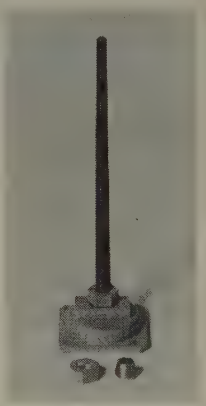


Fig. 2—Ferrod radiator with optimum taper.

This short feeding section (0.32 inch long) is designed to support the ferrod radiator and to lock its position after adjustment. It also reduces the machining tolerances necessary for the ferrod and minimizes the time necessary to make final adjustments in the various types of arrays. Impedance matching is accomplished

[9] Advance Electric and Relay Co., Solenoid SEIC-1600 D. The magnetic field is given by H (oersteds) = 3.9 I(ma).
[10] A. G. Fox, S. E. Miller, and M. T. Weiss, "Behavior and applications of ferrites in the microwave region," *Bell Sys. Tech. J.*, vol. 34, pp. 5–103; January, 1955.
[11] R. C. LeCraw, "High speed magnetic pulsing of ferrites," *J. Appl. Phys.*, vol. 25, pp. 678–679; May, 1954.

by adjusting the length of the ferrod inside the waveguide, this adjustment being made less critical by a short taper at the input end of the rod. Input vswr's less than 1.2, over a 5 per cent frequency band, and half-power beamwidths of less than 28° were not difficult to obtain with this single radiator.

A conservative power rating for the ferrod antenna is 20 watts of average power per rod. The maximum rating depends upon the rf losses in the ferrite and its environment. With presently available ferrites, it is believed that this power handling capability can be extended to 50 w. When only the dielectric property of a ferrite, which is insensitive to temperature changes, is made use of in the antenna array, it is expected that an average power of 100 w per rod would have little effect on the performance of the antenna.

Linear Ferrod Arrays

Several types of linear arrays with ferrods coupled from the narrow side of rectangular waveguide have been constructed. Two of these antennas are shown in Fig. 3. This type of end-fed array is easy to construct and its length can be extended to give radiation patterns with more narrow beams. The individual elements are spaced λ_g apart, resulting in maximum radiation along the axis of the ferrods. The radiation pattern of this broad-side antenna is a narrow fan-shaped beam. Small matched loads or adjustable shorts are used to terminate the section of the waveguide making up the array, depending upon its length and application.

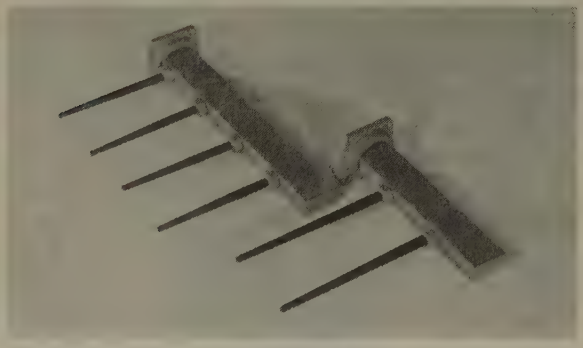


Fig. 3—Two linear ferrod arrays showing one method of coupling.

Another similar type of linear array, but center-fed, is shown in Fig. 4. The microwave energy is coupled into the waveguide from the back of the array through a small ferrite rotating-type switch. Thirty-db switching and a half-power beamwidth of 7° were obtained with this antenna system. Short matched loads are used at each end of the waveguide section to minimize internal reflections.

The positions of the ferrods with respect to the field distribution in several linear arrays are shown in Fig. 5. The ferrods are placed at positions of maximum magnetic field and minimum electric field. The positions of electric field are indicated by crosses and dots at the



Fig. 4—Linear ferrod array with ferrite switch (or modulator) at input.

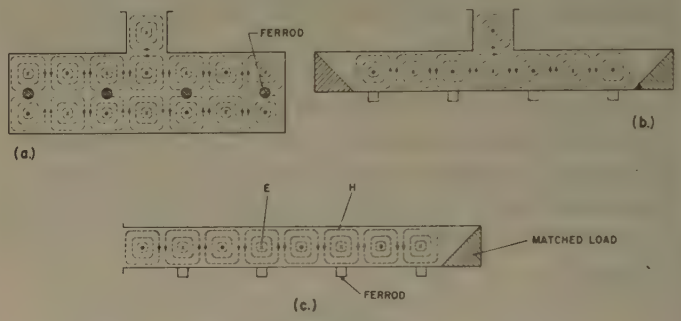


Fig. 5—Linear arrays showing magnetic coupling of ferrod radiators.

center of the magnetic loops (H_{min}). Fig. 5(a) shows the field distribution inside a TE_{207} rectangular cavity-fed array. The ferrod radiators can be coupled from either the top (as shown) or the side of this low-Q cavity.

Stacking one linear array above another narrows the beamwidth of the radiated energy in the vertical plane and thus increases the gain of the system. Several arrangements that were used are shown in Fig. 6. Phase shifters may be used between the individual arrays to insure in-phase excitation of all the radiating elements, and matched loads are used where necessary.

Consideration has also been given to the construction of long linear arrays for obtaining very narrow fan-shaped beams. One of these arrays, shown in Fig. 7, has a beamwidth of approximately 4°, and its side lobe amplitudes are down at least 18 db from that of the main beam. Its measured gain is approximately 140. This center fed array has matched loads at both ends and it is approximately 22 inches long. The work on these long arrays is being continued.

Cavity-Fed Arrays

Another type of antenna array has been designed with ferrod radiators magnetically coupled from resonant cavities. These small cavity arrays are easy to construct and in general give higher gains than the linear arrays previously described.

The field distribution and position of the ferrods inside a TE_{304} mode cavity, are shown in Fig. 8. The magnitudes, directions, and positions of the electric and

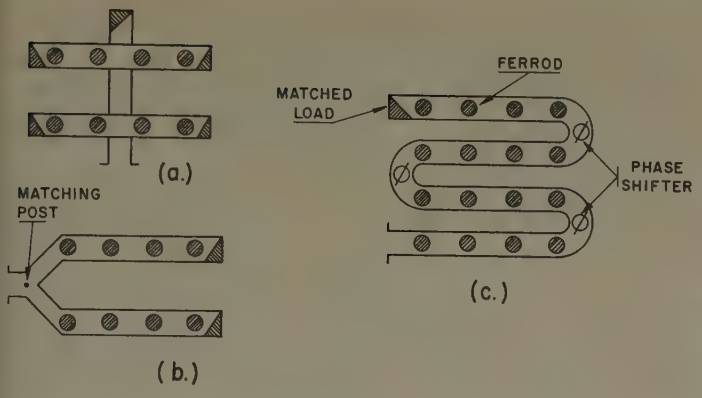


Fig. 6—Stacking of linear arrays.

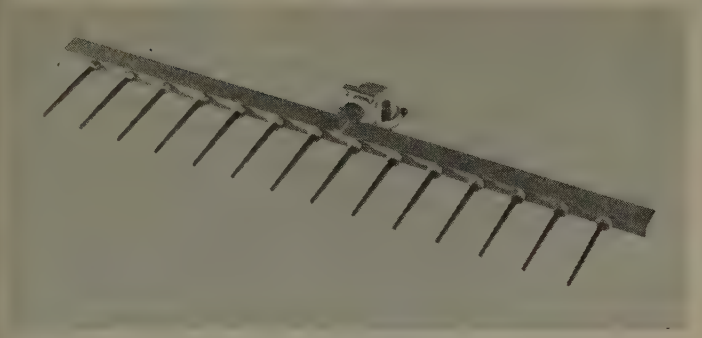


Fig. 7—Long linear ferrod array.

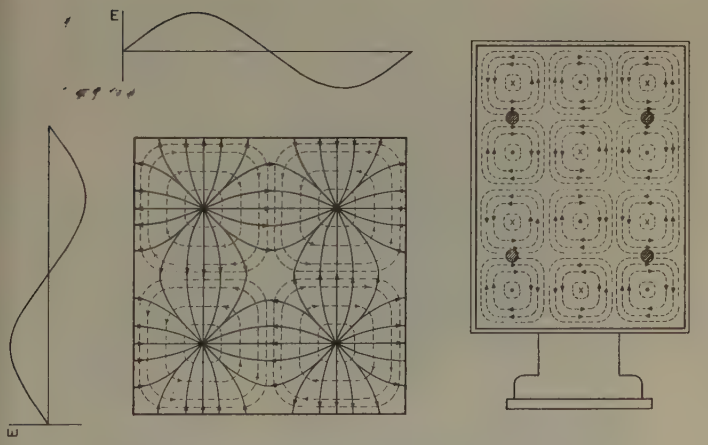


Fig. 8—Field distribution inside a TE_{304} mode cavity feeding a 4-ferrod square array.

magnetic fields can be seen in the drawing at the right, as well as the positions of the ferrods (shaded circles) at points of maximum magnetic field. Positions of maximum electric field are indicated by the crosses and dots at the center of the magnetic loops.

An expanded view of a section of this rectangular cavity, also showing current lines, can be seen at the left of the figure. The position of zero electric and zero magnetic field can be seen to exist at the exact center of this diagram. Shorting posts, 1/16-inch diameter, are placed at these positions to insure the proper mode of oscillation of the cavity (suppress lower order modes) and to insure in-phase excitation of the ferrod radiators.

A photograph of this cavity and a smaller one which is resonant in the TE_{203} mode are shown in Fig. 9. The positions of the 6 shorting posts of the TE_{304} cavity and the 2 used in the TE_{203} mode cavity can be seen in this figure. The dimensions of the TE_{203} cavity are $1.75 \times 2.75 \times 0.50$ inches, and the TE_{304} mode cavity, $3.75 \times 2.75 \times 0.50$ inches.

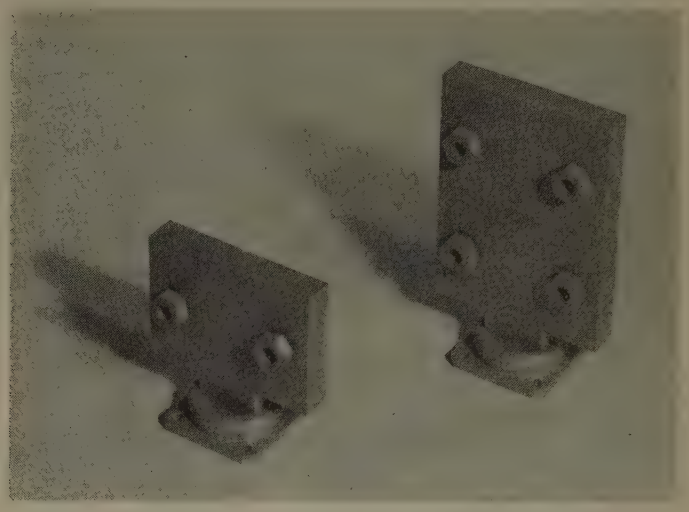


Fig. 9—Linear and square cavity feed arrays.

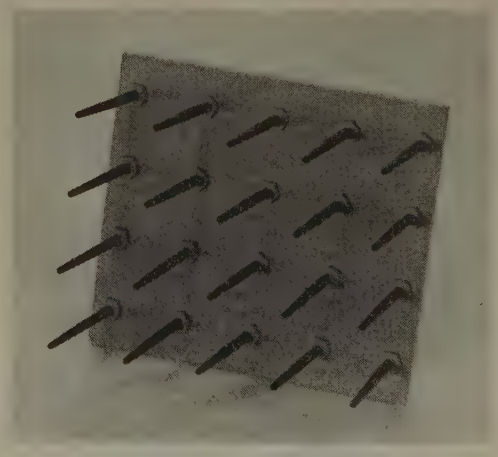


Fig. 10—TEM_{809} mode cavity-feed array.

This cavity technique has been extended to obtain even sharper radiating beams and higher gains. An example of this is shown in Fig. 10. The waveguide feed enters the back at the center of the cavity. The shorting pins (or mode filters) at positions of zero electric and magnetic fields can be seen as small circles between the ferrods. The dimensions of this TE_{809} mode cavity-feed array are $7.0 \times 7.75 \times 0.5$ inches and its measured beamwidth is approximately $6 \times 7°$.

Ferrite-Filled Cylindrical Waveguide Devices

In order to utilize the small size of the ferrod antenna system, compact microwave switches and circulators were designed for array switching and beam lobing.

These devices use a longitudinal magnetic field applied to a ferrite-filled section of cylindrical waveguide, similar to those shown in Figs. 1 and 4.

Operation of these devices depends upon the variable magnetic properties of the ferrite as shown in Fig. 11. These curves[8] show the magnitude of the dispersive components of the scalar permeability ($\mu' \pm K'$) of the R-1 ferrite below magnetic saturation for the positive and negative circularly-polarized waves respectively. Since a linear wave may be considered to be composed of two circularly-polarized waves, the effective permeability (μ'_{eff}) has been included in the figure. It is interesting to note that the ferrite has a permeability less than unity at these frequencies in the absence of a bias field.

A small microwave switch which makes use of the tensor characteristic of the ferrite is shown in Fig. 12.

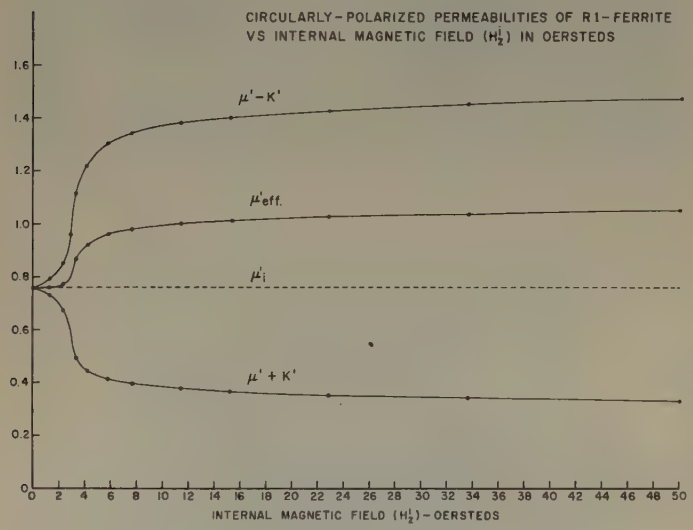


Fig. 11—Real components of the circularly-polarized permeabilitie of R-1 ferrite below magnetic saturation.

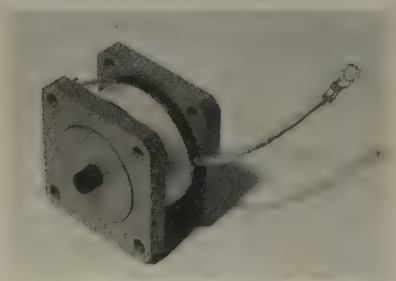


Fig. 12—Ferrite-filled cylindrical waveguide switch.

It consists of a $\frac{1}{4}$-inch diameter ferrite-filled cylindrical waveguide section inside a low-field solenoid. The ferrite protrudes approximately $\frac{1}{8}$ inch into the rectangular waveguide which is used with the switch. When no current flows through the solenoid, the switch is ON, and the microwave energy propagates through the device with essentially no change. With approximately 10 ma of solenoid current, the microwave energy is rotated 90° by the magnetized ferrite and is rejected by the cross-polarized rectangular waveguide at the output. This switch has an insertion loss of about 0.6 db when the switch is ON, and an isolation of greater than 30 db when a magnetic field is applied.

By using a slightly smaller ferrite-filled cylindrical waveguide section, this same switch can be made to operate as a waveguide-below-cutoff switch.[12] When current flows in the solenoid, the effective permeability of the ferrite is increased sufficiently to allow the ferrite-filled section of waveguide to be near, but above cutoff. With no current in the solenoid, the effective permeability is decreased and the waveguide is operating below cutoff. Greater than 50 db switching is obtained with this device when used in this manner.

A rotating flange is used at one end of this switch to allow the position of the output waveguide to be adjusted. This permits higher isolations in the OFF position and lower insertion losses in the ON position when the device is used as a rotation type switch. The switch is $1\frac{1}{8}$ inches long and requires less than 20 ma of current in the solenoid (approx. 80 oersteds) for operation at 3-cm wavelength.

Another ferrite device making use of the Faraday effect is shown in Fig. 13. Its construction is essentially

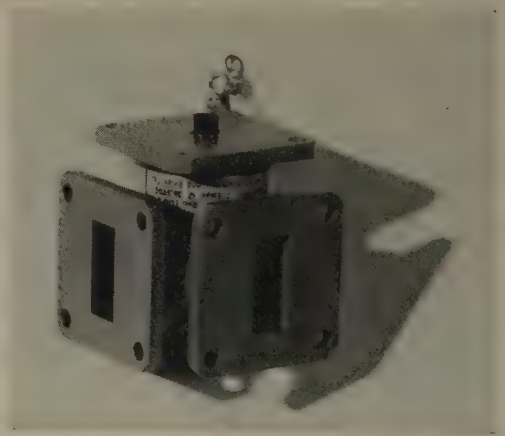


Fig. 13—Three-port microwave switch with ferrite-filled cylindrical waveguide input.

the switch shown in Fig. 12, inserted into a right-angle waveguide bend. The microwave energy enters the ferrite-filled section of waveguide where its plane of polarization is acted upon by an external magnetic field. By rotating the plane of polarization through 90°, energy propagating through one arm can be switched to the other. Greater than 20 db switching has been obtained with this circulator with less than 20 ma of solenoid current. Several of these units in tandem could be used to perform more complex functions in other antenna systems.

[12] F. Reggia, "Magnetically-controlled Microwave Switch with High Isolation," Diamond Ordnance Fuze Labs., TM 41.04-16, unpublished report; May, 1955.

Array Switching and Lobing

The small ferrite switch of Fig. 1 can be used to control the power transmitted from each radiating element of a ferrod antenna system. The switches shown in Figs. 4 and 12 can be used to control (or modulate) the power transmitted by all radiating elements simultaneously.

The 3-port microwave switch of Fig. 13 has been used effectively in beam lobing systems such as that shown in Fig. 14. The two linear ferrod arrays, rotated azimuthally from each other, are alternately excited by the ferrite switch. Any angle of rotation between the radiating beams can be designed into this antenna system, depending upon its use. The advantage of this system over others tried is the requirement of only one control solenoid.

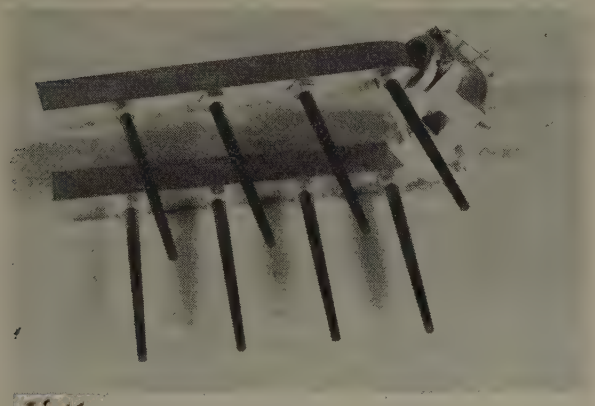


Fig. 14—Beam lobing ferrod antenna system incorporating three-port microwave switch.

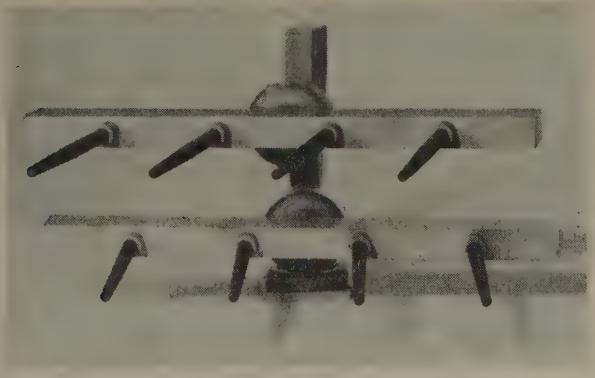


Fig. 15—Beam lobing ferrod array, showing magnetic lobing switches.

Placing one linear array above another on a section of twisted waveguide gives another type of beam lobing system as shown in Fig. 15. A small rotation type ferrite switch in each array provides the necessary beam switching from one array to the other. Any number of these linear arrays can be stacked to obtain greater azimuthal range. When using this antenna system in direction-finding radars, out-of-phase square waves are applied to the two solenoids. Lobing rates of a few kilocycles have been used with the solenoids shown.

Array Scanning

Several methods for obtaining electrical beam scanning have been tried. One method is to apply a longitudinal magnetic field directly to the feed section of a ferrod radiator. Phase shifts up to 50° have been obtained by this technique with little change in the radiated power or plane of polarization. Another method is to apply a transverse magnetic field to a ferrite slab placed in the position of a circularly-polarized rf magnetic field inside the rectangular waveguide section making up the array as shown in Fig. 16. A phase shift of 90° is not difficult to obtain with this technique. Adjustable ferrite-loaded cavities along the narrow side of the waveguide and inside larger cavity-fed arrays have also been used to obtain a scanning angle up to 10°. A phase shift of 90° between the individual ferrod radiators, spaced λ_g (approximately $3/2\ \lambda_0$) apart, is necessary for a 10° shift of the radiated beam.

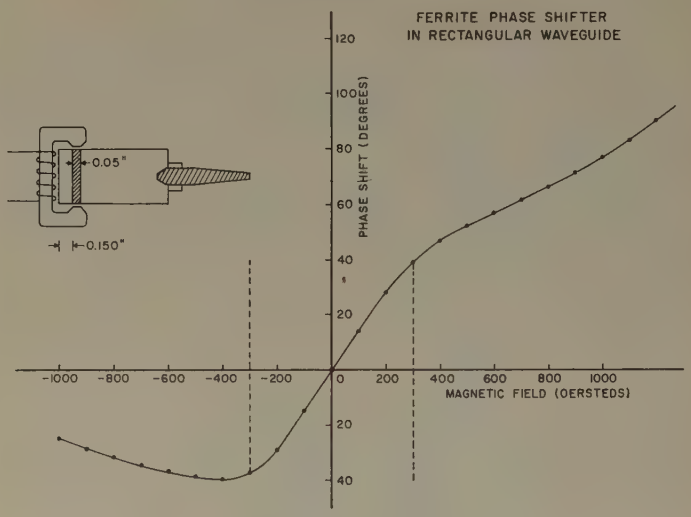


Fig. 16—Nonreciprocal phase shifter in rectangular waveguide.

Circular scanning can be obtained by combining a horizontal and a vertical linear scanning array. By applying an ac voltage to the horizontal scan winding 90° out of time phase with the voltage on the windings for the vertical scan, a nearly circular scan will result. This ac source could also be modulated to produce a spiral scan.

Rotation of Plane of Polarization

Radiation, first in one plane of polarization and then in another, can be had simply by applying a longitudinal magnetic field to the individual ferrod radiators. An example of this could be the antenna system shown in Fig. 1, without the wire mode filter. This change of polarization by a magnetized ferrod radiator vs the dc control current is shown in Fig. 17. A rotation of 180° is obtained with less than 0.2 db change in the power transmitted with 12 ma of solenoid current ($H_0 \approx 47$ oersteds).

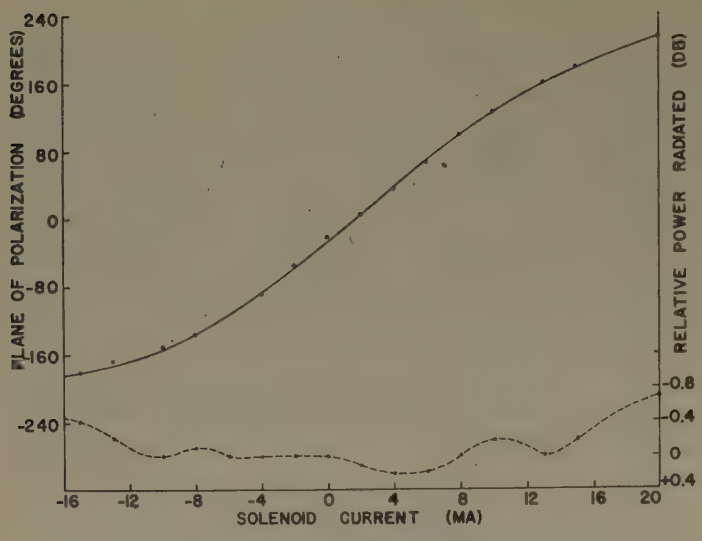


Fig. 17—Rotation of the plane of polarization of radiated energy from ferrod radiator at 9430 mc.

Circularly-Polarized Radiators

A circularly-polarized radiation field can be obtained by exciting the ferrod from the broad side of a properly terminated waveguide. This position of circularly-polarized field, where the x and z components of the rf magnetic field are in time quadrature and of equal magnitude, is located along a plane approximately one-fourth the distance across the waveguide. Either sense of rotation can be had by choosing the correct side of the waveguide.

Radiation Patterns

The radiation characteristics of single and multi-element ferrod radiators of different lengths, diameters, and shapes have been obtained in the frequency range between 9000 and 10,000 mc. The single ferrod radiators were excited from the end of rectangular waveguides, as seen in Fig. 2, and the multi-element arrays were coupled from the narrow side of rectangular waveguides or from resonant cavities as previously described.

A simplified circuit arrangement used for the radiaton pattern measurements is shown in the block dia-

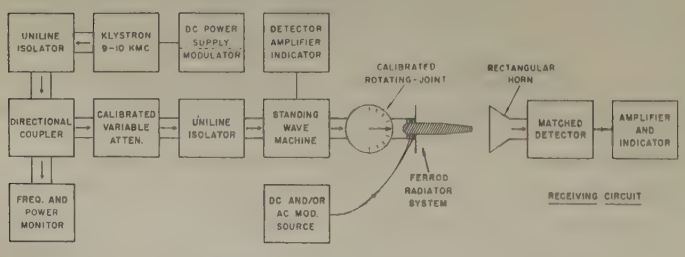


Fig. 18—Simplified circuit arrangement for radiation pattern measurements.

gram of Fig. 18. A carefully selected waveguide rotating-joint, calibrated at the operating frequencies, was used to rotate the ferrod antennas in the azimuthal plane. Another rotating mechanical device was used in the receiving circuit to rotate both the rectangular horn and the matched detector for determining the plane of polarization of the radiated energy. A more accurate antenna measuring system was also used over a much longer path, free from all obstructions. In the latter system, the entire transmitting circuit was rotated and an automatic recorder was used in the receiving circuit.

The directivity of a single untapered ferrod radiator (0.240-inch diameter) fed from the end of a rectangular waveguide vs its length, at 9500 mc, is shown at the left in Fig. 19. The minor lobes have been left out to simplify the drawing. The decreasing width of the main beam with increasing length of the ferrod can be seen in this figure. The gain of a single untapered ferrod radiator 4.5 inches long was found to be approximately 20 at this frequency.

A comparison between the radiation patterns of a tapered and an untapered ferrod radiator, 3.5 inches long, is shown at the right of this figure. Although the untapered ferrod gives a more narrow beamwidth, the power radiated in its side lobes is excessive. This side lobe radiation is almost completely eliminated by the tapered ferrod but not without an increase in the width of the main beam. By increasing the length of the tapered ferrod, the original value of the beamwidth can be restored.

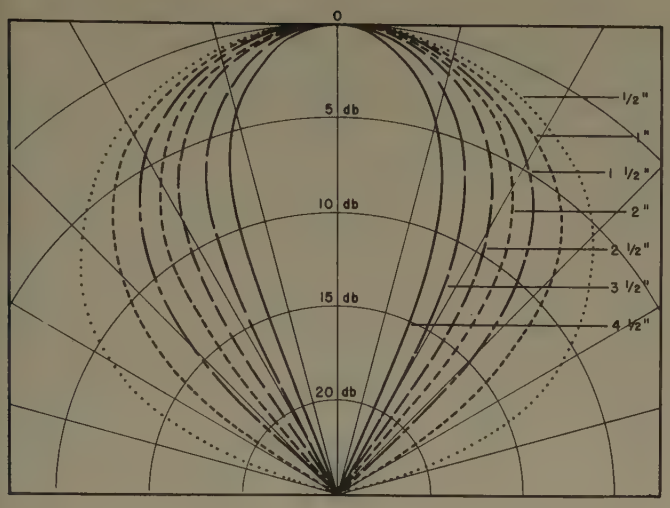
The radiation characteristics of single ferrod radiators 5.5 inches long vs the length of tapers at 9300 mc (at right) and 9600 mc (at left) are shown in Fig. 20. Their diameters were 0.240 inch at the input end and 0.152 inch at the output end.

The length of taper giving the best results was approximately 4 inches. The beamwidth can be seen to increase with increasing length of taper and with decreasing frequency. The gain of the ferrod with the 4-inch taper was compared to that of a standard horn and found to be approximately 35. Impedance matching resulting in vswr's less than 1.2 is not difficult to achieve with these ferrods when coupled from the end of a waveguide section.

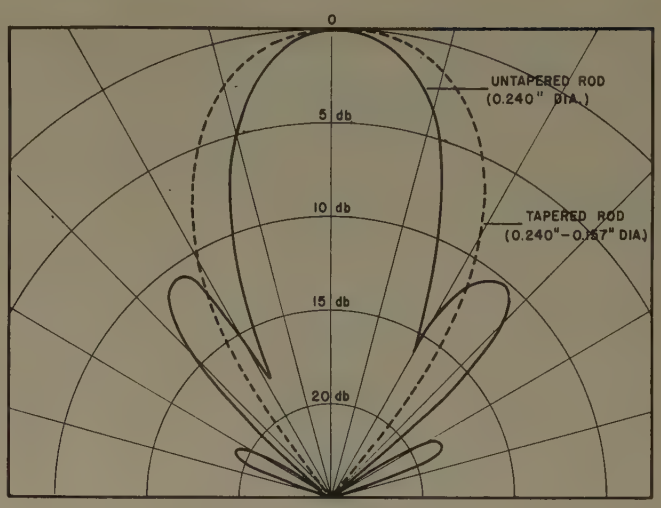
The radiation pattern of another single ferrod 5.4 inches long, but with a slightly larger diameter (0.270 inch), over the frequency range of 9400 ± 200 mc is shown in Fig. 21. The length of taper which gave the best results was found to be 5 inches. The input impedance for this diameter ferrod, when excited from the end of a waveguide section, remained relatively constant over the 400-mc bandwidth. A beamwidth of 30° and a measured gain of approximately 35 were obtained with this radiator.

The radiation characteristic in the azimuthal plane of a 4×5 ferrod array excited from the TE_{809} resonant cavity at 9500 mc is shown in Fig. 22. A beamwidth of approximately 7° and a gain of approximately 130 were obtained for this array which had a somewhat square-shaped beam. A photograph of this antenna is shown in Fig. 10.

The radiation patterns, in the plane of the ferrods,

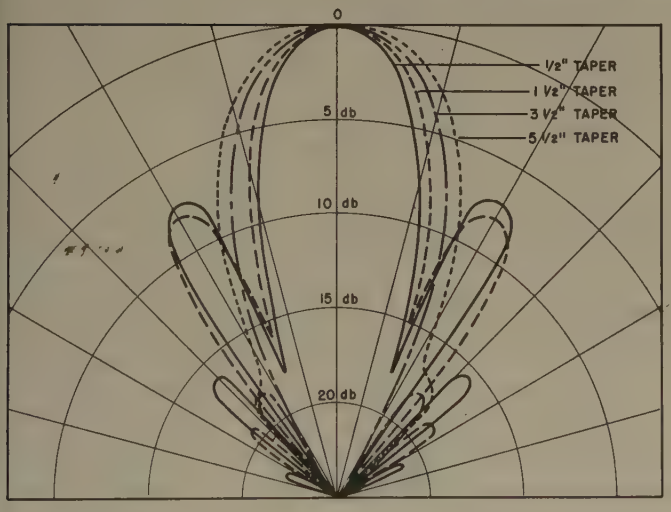


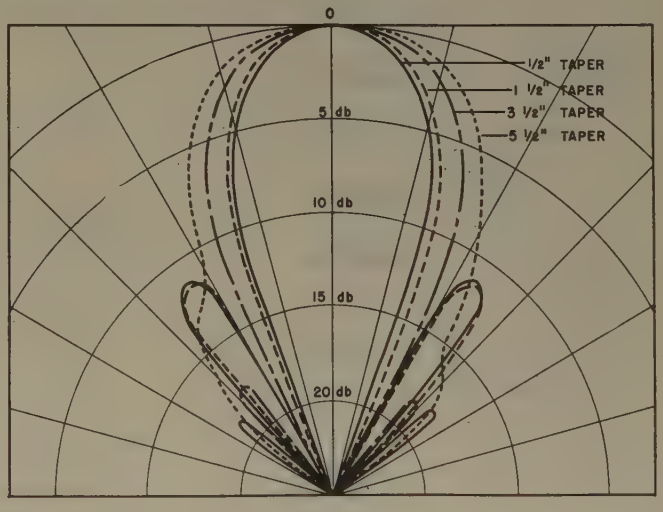
DIRECTIVITY VS. LENGTH OF SINGLE FERROD RADIATORS
(0.240" DIA.)
GAIN OF 4 1/2" FERROD > 20
END FED FROM 1/2" X 1" WAVEGUIDE



RADIATION PATTERN OF SINGLE FERROD RADIATORS
(3 1/2" LONG)
END FED FROM 1/2" X 1" WAVEGUIDE

Fig. 19—Radiation patterns of single ferrod radiators.





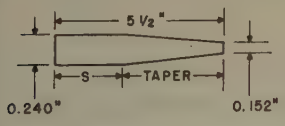
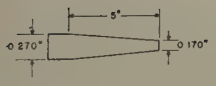


Fig. 20—Radiation patterns of single ferrod radiators 5.5 inches long. Parameter: Length of taper. End fed from $\frac{1}{2}\times$1-inch waveguide. Gain of ferrod with $3\frac{1}{2}$-inch taper approx. 40.



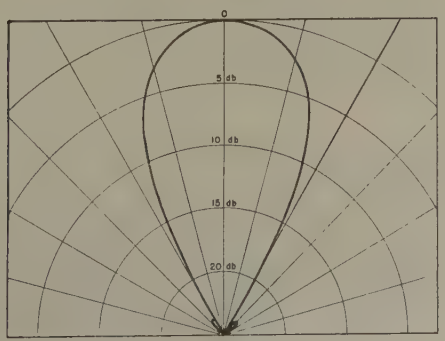


Fig. 21—Radiation pattern of a single ferrod radiator 5.4 inches long.

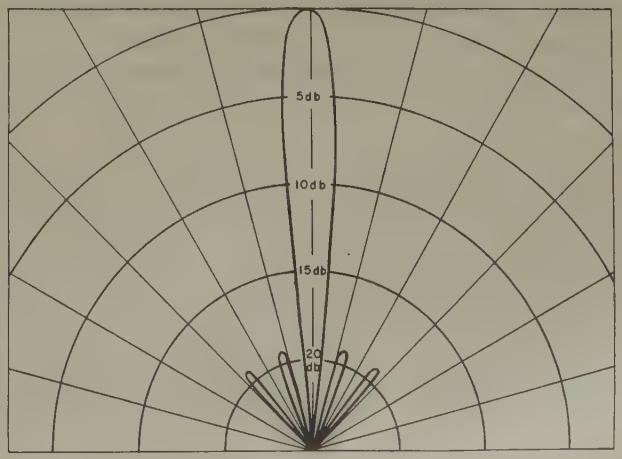


Fig. 22—Azimuthal radiation pattern of cavity-fed (TE_{809}) ferrod antenna.



Fig. 23—Radiation pattern of two linear ferrod arrays. Radiating elements spaced approx. $3/2\lambda_0$ apart.

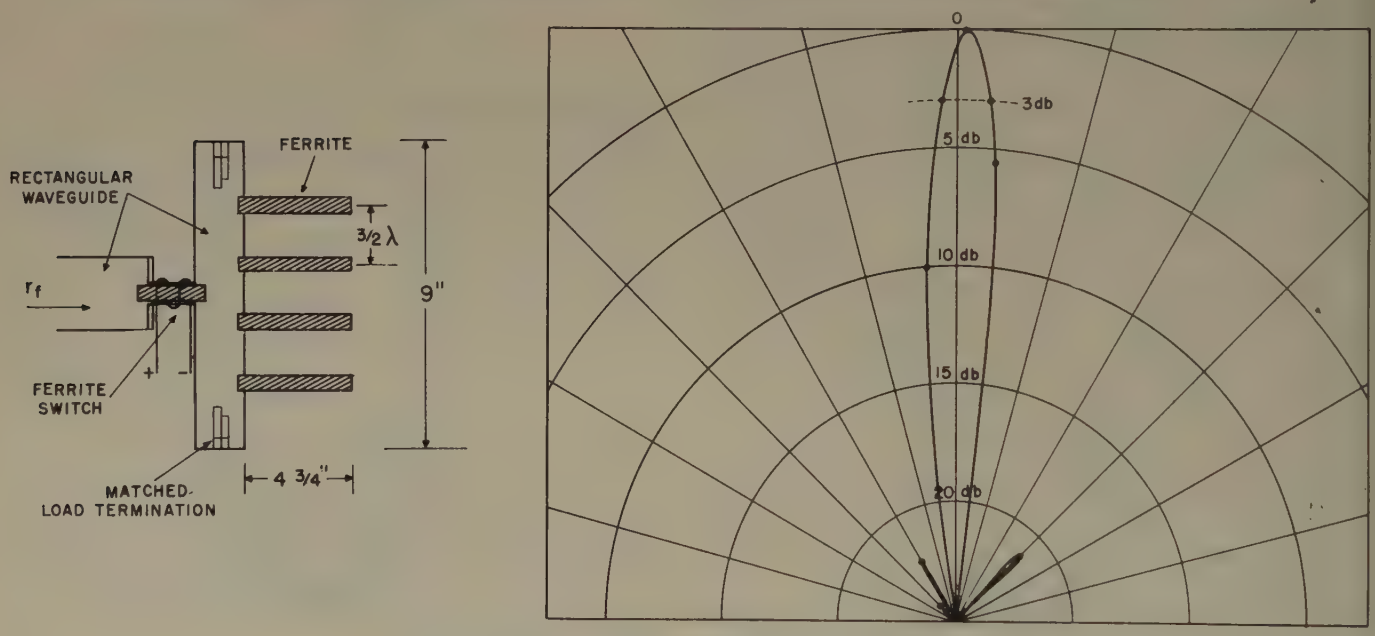


Fig. 24—Radiation pattern of a linear array of four ferrods.

or two linear arrays are shown in Fig. 23. The ferrods were 5 inches long and spaced λ_0 apart along the narrow side of a section of rectangular waveguide. The beamwidth for the arrays can be seen to decrease with increasing number of ferrods, resulting in higher gain antennas. The vertical beamwidth of both arrays was approximately that of a single rod, resulting in a fan-shaped beam. A photograph of this type antenna is shown in Fig. 3.

A simplified drawing of a 4-rod linear array and its radiation characteristics in the plane of the ferrods is given in Fig. 24. The one-half power beamwidth in this plane was approximately 7° and in the vertical plane was that of a single ferrod. Details of the ferrod radiators and the associated modulating system are shown at the left. Short matched loads are used at each end of the waveguide section to minimize internal reflections. A photograph of this antenna is shown in Fig. 4.

Conclusion

The ferrod radiator systems described above are especially useful in the field of portable radars and have good possibilities in the miniaturization of fire-control antenna systems requiring high-speed electrical scanning or lobing. Advantages of these antenna systems include simplicity, low construction costs, no moveable parts, microsecond response to an applied magnetic field, small control currents, and the possibility of relatively broad-band operation at microwave frequencies.

Acknowledgment

We should like to thank Mary Ann Armistead for her assistance in setting up various microwave measurements and for taking some of the data, Mary M. Borda for making the many detailed drawings, and A. J. Pannone of the National Bureau of Standards Grinding Shop for preparing the ferrods.

IRE Standards on Piezoelectric Crystals—The Piezoelectric Vibrator: Definitions and Methods of Measurement, 1957*

57 IRE 14. S1

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Introduction

In 1949, a standard on piezoelectric crystals[1] was issued which covered the definition of axes for piezoelectric crystals and their relation to orthogonal axes, standards for specifying crystal plate orientation, and nomenclature referring to the piezoelectric relations, symbols, and units. It is the object of this present standard to specify the nomenclature and a practical method of measuring the various quantities associated with piezoelectric vibrators.

1.0 The Piezoelectric Vibrator and Its Equivalent Circuit

1.1 The Piezoelectric Vibrator

A piezoelectric vibrator consists of an element cut from piezoelectric material usually in the form of a plate, bar, or ring, and with electrodes attached to or supported near the element to excite one of its resonance frequencies.

1.2 The Equivalent Circuit

The properties of any mode of a lightly-damped mechanical vibrating system, piezoelectrically excited through electrodes which form a two-terminal network, can be represented near resonance by an equivalent electric circuit (Fig. 1) which consists of a capacitance

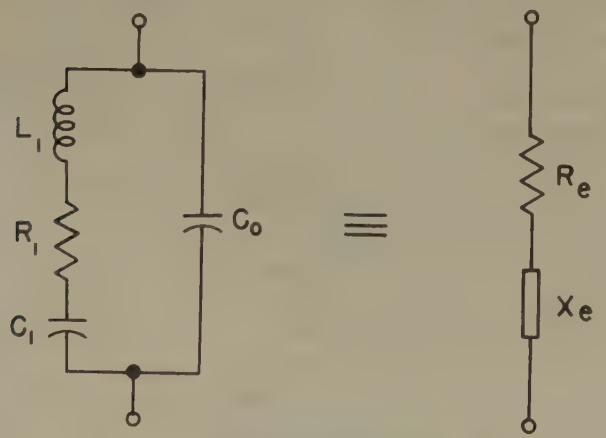


Fig. 1—Equivalent electric circuits of a piezoelectric vibrator.

C_1, inductance L_1, and resistance R_1, in series, shunted by a second capacitance, the parallel capacitance C_0.

These are the fundamental parameters of the piezoelectric vibrator. The representation of a piezoelectric vibrator by the circuit of Fig. 1 is useful only if the four parameters are constant and independent of frequency and amplitude.

The parameters are independent of frequency if the vibrator has no other mode of motion near its resonance. Generally, the mode in question is sufficiently isolated from other modes to permit this assumption. *When this is not true, the equations and measuring methods outlined herein do not apply.* The validity of the circuit representation can be determined by measuring and plotting the impedance or admittance of the vibrator as a function of frequency.

At a given frequency the parameters of the equivalent circuit generally approach constant values as the amplitude of vibration approaches zero. The amplitude which can be tolerated before the parameters are appreciably affected varies widely between vibrators of various types and can only be determined by experiment.

1.3 Parameters of Piezoelectric Vibrators

The four fundamental parameters C_1, L_1, R_1, and C_0 define the network completely and all other parameters may be derived from them. The important parameters of a piezoelectric vibrator are listed in Table I. The equation for the impedance Z (or admittance Y)

$$Z = \frac{1}{Y} = \frac{1}{j}\cdot\frac{\omega_s}{\omega}\cdot\frac{R_1 Q}{r} \cdot \frac{1 + jQ\left(\frac{\omega}{\omega_s} - \frac{\omega_s}{\omega}\right)}{1 + jQ\sqrt{\frac{1+r}{r}}\left(\frac{\omega}{\omega_p} - \frac{\omega_p}{\omega}\right)} \cdots \quad (1)$$

of the equivalent electric circuit of the piezoelectric vibrator is the basic equation for deriving the relations of the various parameters. For the symbols used in (1) see Table I.

For the purpose of defining the different characteristic frequencies, the impedance Z of the equivalent network, its resistive component R_e, its reactive component X_e, and the reactance of X_1 of the L_1, C_1, R_1 branch are plotted as functions of frequency in Fig. 2. These curves,

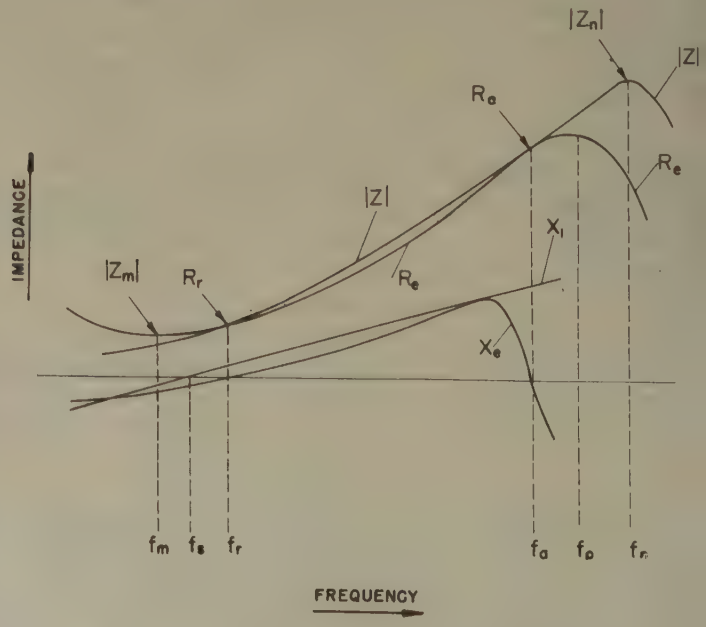


Fig. 2—Impedance $|Z|$, resistance R_e, reactance X_e, and series arm reactance X_1 of a piezoelectric vibrator as a function of frequency. For the meaning of the different symbols, see Table I.

[1] "Standards on Piezoelectric Crystals," Proc. IRE, vol. 37, pp. 1378–1395; December, 1949.

TABLE I

PARAMETERS OF THE EQUIVALENT CIRCUIT OF A PIEZOELECTRIC VIBRATOR

C_1 = Motional Capacitance

L_1 = Motional Inductance

R_1 = Motional Resistance

C_0 = Shunt (Parallel) Capacitance

$r = \frac{C_0}{C_1}$ Capacitance Ratio

Characteristic Frequencies:

f_m = Frequency at Maximum Admittance (Minimum Impedance)

f_s = Motional (Series) Resonance Frequency = $\frac{1}{2\pi\sqrt{L_1C_1}}$

f_r = Resonance Frequency (Reactance $X_e = 0$)

f_a = Antiresonance Frequency (Reactance $X_e = 0$)

f_p = Parallel Resonance Frequency = $\frac{1}{2\pi}\sqrt{\frac{1}{L_1C_1}\left(1+\frac{1}{r}\right)}$

f_n = Frequency at Minimum Admittance (Maximum Impedance)

$Z = \frac{1}{Y} = R_e + jX_e$ = Impedance of Vibrator

Z_m = Impedance at f_m (Minimum Impedance)

Z_n = Impedance at f_n (Maximum Impedance)

Y_m = Admittance at f_m (Macimum Admittance)

Y_n = Admittance at f_n (Minimum Admittance)

R_r = Impedance at f_r, Resistive (Resonance Resistance)

R_a = Impedance at f_a, Resistive (Antiresonance Resistance)

$Q = \frac{\omega_s L_1}{R_1}$ = Quality Factor

$M = \frac{Q}{r} = \frac{1}{\omega_s C_0 R_1}$ = Figure of Merit

$\omega = 2\pi f$

L_0 = Inductance in Parallel with Vibrator

C_L = Load Capacitance

R_{st} = Standard Resistor

$f_{m\pi}$ = Frequency of Maximum Transmission

f_{sL} = Motional Resonance Frequency of Combination of Vibrator and C_L

f_{mTL} = Frequency of Maximum Transmission of Combination Vibrator and C_L

R_{1L} = Resulting Motional Resistance of Combination DF Vibrator and C_L

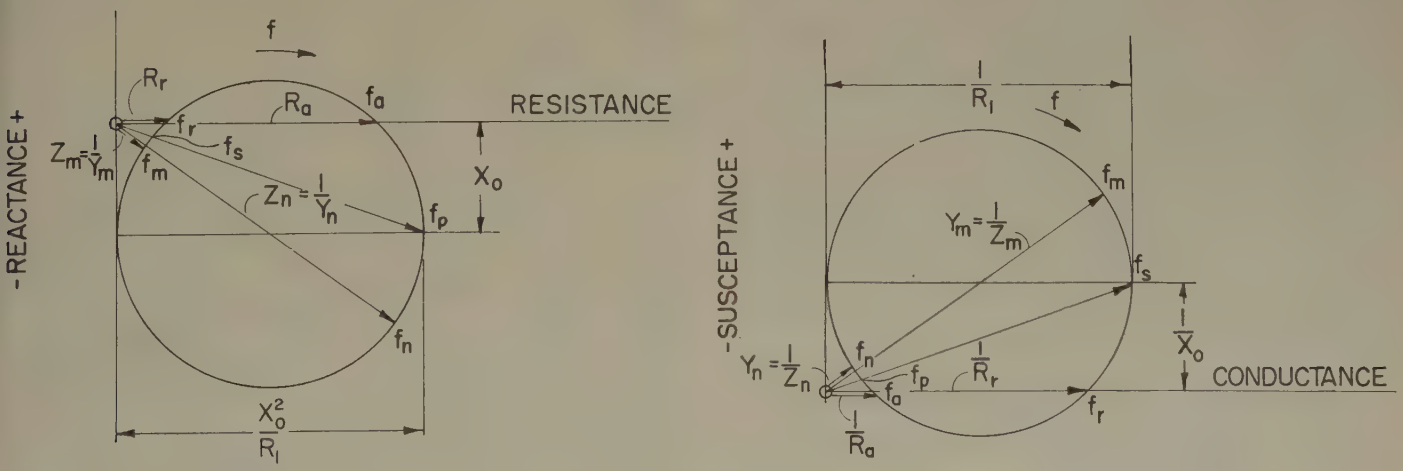


Fig. 3—Impedance and admittance diagram of a piezoelectric vibrator. The symbols conform with those used in Table I and Fig. 2.

however, have only qualitative character and do not represent a particular piezoelectric vibrator. Further, to clarify the situation, the impedance and admittance circles of a piezoelectric vibrator are reproduced in Fig. 3. The circle representation of the impedance or admittance of a piezoelectric vibrator is valid only if, in the admittance diagram, the circle diameter is large in comparison with the change of ωC_0 in the resonance range. If the latter condition is not fulfilled, the admittance curve shows a more complicated character.

TABLE II

RELATIONS BETWEEN THE CHARACTERISTIC FREQUENCIES OF A PIEZOELECTRIC VIBRATOR

CHARACTERISTIC FREQUENCY	1ST APPROXIMATION		2ND APPROXIMATION	
	$\frac{f}{f_s}$	DEVIATION $\frac{\Delta f}{f_s}$ FROM MORE PRECISE VALUE	$\frac{f}{f_s}$	DEVIATION $\frac{\Delta f}{f_s}$ FROM MORE PRECISE VALUE
f_m	$\frac{f_m}{f_s}=1$	$-\frac{1}{2M^2r}$	$\frac{f_m}{f_s}=\sqrt{1+\frac{1}{2r}\left[1-\sqrt{1+\frac{4}{M^2}}\right]}$	$\frac{1}{2M^4r^2}$
f_r	$\frac{f_r}{f_s}=1$	$\frac{1}{2M^2r}$	$\frac{f_r}{f_s}=\sqrt{1+\frac{1}{2r}\left[1-\sqrt{1-\frac{4}{M^2}}\right]}$	$\frac{1}{2M^4r^2}$
	$\frac{f_a}{f_s}=1+\frac{1}{2r}$	$-\frac{1}{2M^2r}\left(\frac{1}{r}+1\right)$	$\frac{f_a}{f_s}=\sqrt{1+\frac{1}{2r}\left[1+\sqrt{1-\frac{4}{M^2}}\right]}$	$-\frac{1}{2M^2r}\cdot\frac{1}{r}$
f_n	$\frac{f_n}{f_s}=1+\frac{1}{2r}$	$\frac{1}{2M^2r}\left(\frac{1}{r}+1\right)$	$\frac{f_n}{f_s}=\sqrt{1+\frac{1}{2r}\left[1+\sqrt{1+\frac{4}{M^2}}\right]}$	$\frac{1}{2M^2r}\cdot\frac{1}{r}$
p	$\frac{f_p}{f_s}=1+\frac{1}{2r}$	$-\frac{1}{8r^2}$	$\frac{f_p}{f_s}=\sqrt{1+\frac{1}{r}}$	0

Since (1) is nonlinear in frequency, it is convenient to make certain approximations in deriving practical equations for general use. It is the error of these approximations, in addition to the instrumentation errors, that governs the over-all accuracy of the derived parameters. Table II gives relations between the characteristic frequencies, f_m, f_r, f_a, f_p, f_n and the series resonance frequency f_s of a vibrator for two different degrees of approximation, and particularly the deviation of the characteristic frequencies from f_s. The first approximation is commonly used in the case of vibrators with high M and r; *i.e.*, high Q, as for instance in the case of quartz vibrators. More exact equations than those of the first approximation have been derived by various authors.[2,3] They are shown in Table II as second approximation. The accuracy of the two approximations is given in columns 3 and 5 in Table II. For a vibrator with $M^2r=1000$, for instance, the error in determining f_s from f_m would be $-5\cdot10^{-4}$ for the first approximation and $-5\cdot10^{-7}$ for the second approximation.

2.0 Methods of Measuring the Parameters of the Equivalent Circuit

2.1 Measurements—General

For production tests, where only frequency and a quality factor are of concern, oscillators are generally used. In this method, the vibrator is part of the oscillator circuit and controls the frequency and magnitude of the output voltage. It is one of the most convenient methods of measurement, particularly for determining effects of temperature variation, and with proper precautions can be used for the determination of all the parameters. The errors due to instrumentation, however, are not as readily specified or controlled as for some of the methods where the vibrator is used as a passive element, and, therefore, oscillators are not as suitable for standard test methods.

Three of the most commonly used methods of the passive type are 1) bridge,[4] 2) Q meter,[4] and 3) transmission circuit[5] methods.

The bridge method may be extended to the measurement of impedance (or admittance) as a function of frequency in the most extreme conditions. This procedure is laborious and generally unwarranted when dealing with an isolated mode. For measurement of critical frequencies and impedances, bridges are generally limited with respect to frequency and impedance range. The transmission circuit is recommended for use in laboratory tests because it is simple, convenient, and involves equipment normally available. It is also used extensively for production tests. With proper consideration of errors of instrumentation and suitable equations, this method is the best suited for the ranges of r and M generally encountered.

[2] G. E. Martin, "Determination of equivalent-circuit constants of piezoelectric resonators of moderately low Q by absolute-admittance measurements," *J. Acoust. Soc. Amer.*, vol. 26, pp. 413–420; May, 1954.

[3] E. A. Gerber, "A review of methods for measuring the constants of piezoelectric vibrators," PROC. IRE, vol. 41, pp. 1103–1112; September, 1953.

[4] W. D. George, M. C. Selby, and R. Scolnik, "Precision measurement of electrical characteristics of quartz crystal units," PROC. IRE, vol. 36, pp. 1122–1131; September, 1948.

[5] L. F. Koerner, "Progress in development of test oscillators for crystal units," PROC. IRE, vol. 39, pp. 16–26; January, 1951.

2.2 Transmission Circuit Method

2.2.1 Type of Measurement: This method of measurement consists of determining the frequency and the impedance at maximum transmission of a π network in which the vibrator under test is the series branch. The frequency at maximum transmission is measured with and without a capacitance C_L in series with the vibrator. From these measurements, f_s, C_1, and R_1 can be determined.

2.2.2 Circuit: The measuring circuit consists of a variable-frequency oscillator, detector, measuring network, and frequency measuring equipment connected in accordance with Fig. 4. The oscillator must have a high degree of purity of output waveform.

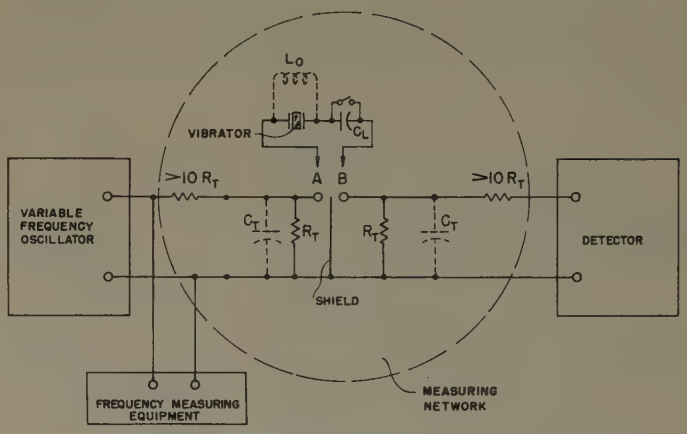


Fig. 4—Transmission measuring circuit.

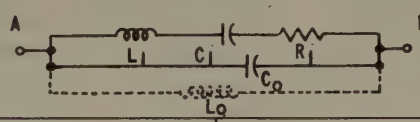
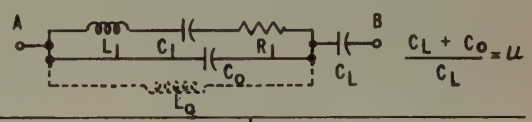
2.2.3 Procedure

2.2.3.1 Motional Resonance Frequency f_s: The frequency of the oscillator is adjusted for maximum transmission with the piezoelectric vibrator connected to terminals A and B of the network. This is the frequency of maximum transmission f_{mT} of the network. At the first approximation, f_{mT} is equal to the frequency of minimum impedance f_m and the motional resonance frequency f_s of the vibrator. If higher accuracy for f_s is required, Table III should be consulted which gives

TABLE III

FREQUENCY ERROR $\frac{\Delta f}{f}=\frac{f_{mT}-f_s}{f_s}$ AND RESISTANCE ERROR $\frac{\Delta R}{R}=\frac{R_{st}-R_1}{R_1}$ FOR SERIES RESONANCE OPERATION, AND FREQUENCY ERROR $\frac{\Delta f}{f}=\frac{f_{mTL}-f_{sL}}{f_{sL}}$ AND RESISTANCE ERROR $\frac{\Delta R}{R}=\frac{R_{st}-R_{1L}}{R_{1L}}$ FOR POSITIVE REACTANCE OPERATION.

THE SYMBOLS USED IN THIS TABLE ARE EXPLAINED IN TABLE I AND FIG. 4

		SERIES RESONANCE OPERATION		POSITIVE REACTANCE OPERATION	
1)					
2)		$\frac{\Delta f}{f}$; $\frac{\Delta R}{R}$	DEVIATION OF $\frac{\Delta f}{f}$ FROM MORE PRECISE VALUE FOR FREQUENCY ERROR	$\frac{\Delta f}{f}$; $\frac{\Delta R}{R}$	DEVIATION OF $\frac{\Delta f}{f}$ FROM MORE PRECISE VALUE FOR FREQUENCY ERROR
3)	FREQUENCY ERROR $\frac{\Delta f}{f}$ DUE TO C_O AND R_T	$-2\,\frac{R_T}{R_1}\,\frac{1}{M^2 r}$	$-\frac{1}{2M^2 r}\,\frac{1}{1+\frac{4}{M^2}\,\frac{R_T}{R_1}}$	$-2\,\frac{R_T}{R_1}\,\frac{1}{M^2 r}\,\frac{1}{u}$	$-\frac{u}{2M^2 r}\,\frac{1}{1+\frac{4}{M^2}\,\frac{R_T}{R_1}}$
4)	FREQUENCY ERROR $\frac{\Delta f}{f}$ DUE TO C_O AND R_T WITH PARALLEL L_O	$-4\,\frac{R_T}{R_1}\cdot\frac{1}{M^2 r}\,\beta$ $\beta=\frac{1}{2}\left(1-\frac{L_O C_O}{L_1 C_1}\right)$	$-\frac{1}{M^2 r}\,\beta\,\frac{1}{1+\frac{8}{M^2}\,\frac{R_T}{R_1}\beta^2}$	$-4\,\frac{R_T}{R_1}\,\frac{1}{M^2 r}\,\beta\,\frac{1}{u}$	$-\frac{u}{M^2 r}\,\beta\,\frac{1}{1+\frac{8}{M^2}\,\frac{R_T}{R_1}\beta^2}$
5)	FREQUENCY ERROR $\frac{\Delta f}{f}$ DUE TO C_T	$\frac{R_T^2\,C_T}{R_1^2\,C_O}\cdot\frac{1}{M^2 r}$	$-\left(4\,\frac{R_T}{R_1}+1\right)\frac{1}{2M^2 r}$	$\frac{R_T^2\,C_T}{R_1^2\,C_O}\,\frac{1}{M^2 r}\,\frac{1}{u^2}$	$-\left(4\,\frac{R_T}{R_1 u^2}+1\right)\frac{u}{2M^2 r}$
6)	FREQUENCY ERROR $\frac{\Delta f}{f}$ DUE TO DETECTOR SENSITIVITY S $S=\frac{\text{SMALLEST DETECT. CURR. CHG}}{\text{CURRENT}}$	$\left(2\,\frac{R_T}{R_1}+1\right)\frac{.707\sqrt{S}}{Mr}$	$-\left(2\,\frac{R_T}{R_1}+1\right)^2\frac{S}{M^2 r}$	$\left(2\,\frac{R_T}{R_1 u^2}+1\right)\frac{.707\sqrt{S}}{Mr}$	$-\left(2\,\frac{R_T}{R_1 u^2}+1\right)^2\frac{u}{M^2 r}\,S$
7)	FREQUENCY ERROR $\frac{\Delta f}{f}$ DUE TO ERROR IN C_L EQUAL TO ΔC_L	—	—	$-\frac{1}{2}\,\frac{\Delta C_L}{C_L}\,\frac{C_O}{C_L}\,\frac{1}{u^2 r}$	—
8)	RESISTANCE ERROR $\frac{\Delta R}{R}$ DUE TO R_T & C_T	$\left(\frac{1}{2}\,\frac{R_T\,C_T}{R_1\,C_O}-1\right)\cdot\frac{8\,R_T}{R_1 M^2}$	—	$\frac{8\,R_T}{R_1 M^2}\left(\frac{1}{2u}\,\frac{R_T\,C_T}{R_1\,C_O}-1\right)$	—

under the heading, "Series Resonance Operation," in lines 3 and 5, the relationship between f_{mT} and f_s, as the ratio

$$\frac{\Delta f}{f} = \frac{f_{mT} - f_s}{f_s},$$

for two different degrees of approximation, as a function of the network parameters.

2.2.3.2 Motional Capacitance C_1: The measurement of 2.2.3.1 is repeated, but with a particular C_L in series with the vibrator. The motional resonance frequency for this combination, f_{sL}, can again be derived from the measured frequency at maximum transmission f_{mTL}, with the help of lines 3, 5, and 7 of Table III, under the heading, "Positive Reactance Operation." C_1 is then obtained from C_L, f_s, f_{sL}, and C_0:

$$C_1 = 2\frac{f_{sL} - f_s}{f_s}(C_0 + C_L). \qquad (2)$$

C_0 can be eliminated and the accuracy of measurement is increased by using two or more different values of C_L.

2.2.3.3 Motional Resistance R_1: The detector reading is adjusted to some convenient reference point and noted. The vibrator is replaced by a standard resistor R_{st} (variable or selected value) to give the same reading as the maximum transmission value for the vibrator. This value of resistance gives approximately the magnitude of minimum impedance $|Z_m|$ of the vibrator. At a first approximation, $R_{st} = |Z_m|$ is equal to R_1. Table III furnishes in line 8 the necessary correction formulas for better approximations. For the sake of completeness, correction data for the resulting motional resistance R_{1L} of the combination vibrator-C_L are also given.

2.2.4 Network Requirements: The accuracy of the results increases as the following conditions are approached:

1) Reactance X_T of terminating capacitance C_T much greater than terminating resistance R_T, ($X_T \gg R_T$).
2) Stray capacitance C_{A-B} between terminals A and B low compared to vibrator capacitance C_0, ($C_0 \gg C_{A-B}$).
3) Reactance of stray capacitance C_{A-B} high compared to series resistance R_1, ($X_{A-B} \gg R_1$).
4) Inductance of leads connecting vibrator low compared to inductance of vibrator.

In the case of vibrators with low figure of merit M, it is advisable to use a shunting coil L_0 connected in parallel with the vibrator. If the combination L_0C_0 is tuned close to the motional resonance frequency f_s of the vibrator, f_s and R_1 will be measured instead of f_{mT} and $|Z_m|$. Table III, line 4, supplies information as to the accuracy of the determination of f_s as a function of L_0C_0/L_1C_1.

Table III supplies additional information in line 6 as to the influence of the detector sensitivity (smallest detectable current-change/current) on the determination of f_s and f_{sL}.

2.3 Measurement of C_0

C_0 of the equivalent vibrator circuit is slightly less than the measured value for a free piezoelectric element and slightly greater than the measured value of the clamped condition of the piezoelectric element. There is, therefore, no simple direct method of measuring C_0 exactly. This difference, however, is generally sufficiently small to be neglected unless the vibrator has a small capacitance ratio; *i.e.*, $r < 50$.

C_0 is usually determined in a capacitance bridge or in the Q-meter at a frequency sufficiently lower than that of all modes of vibration of the vibrator to reduce their effect as far as possible. Where greater accuracy is required, use must be made of the fact that the dielectric permittivity depends upon the mode of vibration. This will be discussed in a subsequent standard.

CORRECTION

The following correction to "IRE Standards on Methods of Measurement of the Conducted Interference Output of Broadcast and Television Receivers in the Range of 300 KC to 25 MC, 1956 (56 IRE 27 S1)," which appeared on pages 1040–1043 in the August, 1956, issue of PROCEEDINGS OF THE IRE, has been brought to the attention of the editors.

On page 1041, the last sentence of paragraph 2.2.2 should read:
(For this requirement the power plug is short-circuited.)

Correspondence

Microwave Ferrite Phase Shifter*

A ferrite phase shift device which appears to have some promise as a sideband modulator or as part of a high speed switch has been tested, and some of the results are reported here.

In one form the arrangement consists of a helical transmission line with a ferrite tube mounted inside the helix. Not only does the ferrite-loaded helix act as a transmission system whose phase shift (or insertion loss) can be varied by varying the permeability of the ferrite, but also as a solenoid which, when properly excited, supplies the low-frequency field that varies this permeability.

When tested as a sideband modulator, the particular arrangement used generated first-order sidebands which were traced continuously, with the exception noted below, from 70 kc to 50 mc with the carrier at 9 kmc. The lower limit was a result of the resolution of the available spectrum analyzer; it is believed that much lower frequency sidebands can be as easily, if not more easily, generated. The upper limit was a result of the high-frequency limit of readily available oscillators; sideband generation was still quite strong at 50 mc. The sidebands were considerably reduced in magnitude and essentially disappeared in a region about 2 mc wide centered at a modulating frequency of 17 mc. This was possibly a domain wall resonance phenomena since the frequency at dropout was somewhat influenced by the dc axial biasing field.

Some understanding of the manner in which the device works can be obtained from an examination of the static transmission characteristics shown in Fig. 1. As might be expected, these transmission characteristics were essentially the same for either direction of axial magnetic field, except for slight hysteresis effects near zero field. In order to test the device as a sideband modulator, the helix was excited at one end (end A—Fig. 2) by a low-frequency oscillator, while the other end (end B—Fig. 2) was terminated in a 50-ohm resistor. By-pass chokes of the usual variety were built into the coaxial low-frequency input and output lines, as shown in Fig. 2, to minimize the microwave energy leakage. Energy at the carrier frequency of 9 kmc was fed into one of the waveguides, and the other waveguide was connected to a spectrum analyzer. If one assumes the phase shift per unit field is linear over a small range of magnetic field, it can be readily shown that for sinusoidal low-frequency modulation the amplitude of the nth order side bands is given by $J_n(sA)$, the nth order Bessel function of argument sA, where

s = total radian phase shift per unit axial modulating field,
A = amplitude of axial modulating field.

From the data in Fig. 1, using the catalog quoted power output of the modulating frequency sources, and assuming the helix performs as an ideal sheath solenoid, it was estimated that in the presence of a small axial dc biasing field the modulation index sA would be approximately 0.01. This leads to first-order sidebands about 46 db down from the carrier. The measured magnitudes of these sidebands were indeed of this order. They were essentially equal, and the variation in their amplitude as a function of a superimposed axial dc field was exactly as would be predicted from the static data.

In summary, the possibilities available from a ferrite-loaded helix as a phase shifter have been demonstrated. The frequency response is believed to be several orders of magnitude higher than any presently available similar devices, with the upper limit probably determined primarily by the ferrite material and not the physical arrangement. Single-sideband generation would appear possible by the use of sawtooth-like modulation on the helix. To increase the phase shift per unit modulating field it is evident that more ferrite loading is required, which can be accomplished, for example, by increasing the length of the ferrite tube or increasing its wall thickness. It also appears clear that the helix parameters as well as the type of ferrite will also influence the modulation index.

The writer would like to acknowledge the helpful discussions held with J. T. Mendel as well as the assistance of G. Lee and A. Iversen, who supplied the rod-supported helix.

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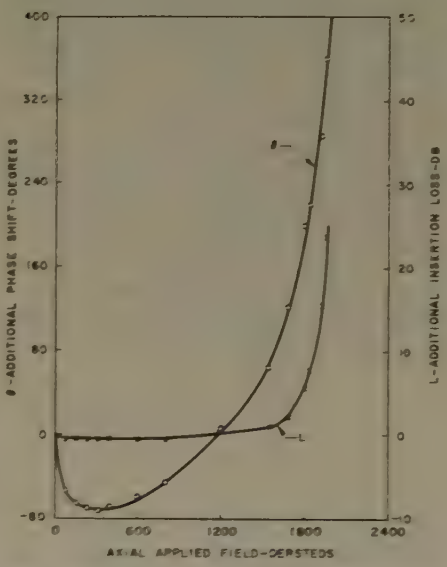


Fig. 1—Additional phase shift and insertion loss of the ferrite-loaded helix as a function of an applied axial magnetic field.

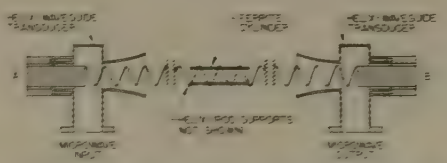


Fig. 2—Cross section of ferrite-loaded helix and end transducers. Helix has an inner diameter of 0.125 inch and is wound of 0.22-inch diameter molybdenum wire with 30 turns per inch. Ferrite cylinder is made of Ferramic R-1 material and is 1 inch long with 0.124-inch outer diameter and 0.094-inch inner diameter. The helix is supported by three sapphire rods (not shown) spaced equally around helix circumference. Waveguide is standard RG-52/U or WR90 with dimensions 1 × ½ × 0.050 (wall), inches.

Stability Requirements and Calibration of Radiometers when Measuring Small Noise Powers*

A radiometer is a receiving equipment designed to measure noise power, usually to an accuracy of better than 1°K in effective noise temperature. In a simple radiometer, where the output is a function of the total noise power at the input, excellent receiver stability is required since equivalent receiver input temperatures of 500° to 3000°K are ordinarily encountered. Dicke modified the simple radiometer such that it periodically measured the difference in noise temperature between a reference termination and the antenna, and thus partially eliminated the need for excellent stability.[1,2] However, measurement of noise temperatures as low as a fraction of 1°K imposes severe requirements on receiver stability even for an improved Dicke system. This note discusses the stability requirements for radiometers when measuring small noise temperatures, and proposes a modification of the Dicke system to alleviate the severe stability requirement. Using this modified Dicke system, it also becomes possible to calibrate small noise temperatures using ordinary noise sources.

In the radiometer proposed by Dicke, an attenuator at temperature T_0 is periodically inserted between the antenna and receiver terminals. The system is designed to measure the difference between the detector output voltage with the receiver connected to the antenna and that with the receiver connected to the attenuator. The following analysis assumes sufficient smoothing in the radiometer (a large bandwidth-time constant product) so that residual noise fluctuations do not limit receiver sensitivity.

* Received by the IRE, November 19, 1956.

* Received by the IRE, November 9, 1956.
[1] R. H. Dicke, "The measurement of thermal radiation at microwave frequencies," *Rev. Sci. Instr.*, vol. 17, pp. 268–275; July, 1946.
[2] C. H. Mayer, "Improved microwave noise measurements using ferrites," IRE TRANS., vol. MTT-4, pp. 24–28; January, 1956.

The difference, or output, voltage, V_R, from a Dicke radiometer with a square-law detector (assuming receiver noise factor and gain do not vary appreciably during a sampling period) can be written as:

$$V_R = CG[(F-1)T_0 + T_A] - CGFT_0 \quad (1)$$

T_A = effective antenna temperature in degrees K

G = receiver power gain

F = receiver noise factor

T_0 = attenuator temperature in degrees K

C = a constant.

If the radiometer characteristics drift, V_R will also drift. To measure T_A to an accuracy ΔT, it is necessary that the change in V_R due to radiometer drift be small compared with the change in V_R due to a variation of ΔT in T_A.

This stability criterion can be expressed as:

$$\frac{\partial V_R}{\partial F}\Delta F + \frac{\partial V_R}{\partial G}\Delta G \ll \frac{V_R}{\partial T_A}\Delta T. \quad (2)$$

Substituting (1) in (2) we obtain the stability criterion:

$$(T_A - T_0)\frac{\Delta G}{G} \ll \Delta T. \quad (3)$$

Eq. (3) indicates the accuracy of temperature measurement to be independent of drifts in receiver noise factor, which is not true when a linear detector is used. It also indicates that for a given accuracy the allowable gain drift is a function of $(T_A - T_0)$, and for values of T_A near T_0 the system is most insensitive to gain drift. [It is interesting to note that (3) for a simple radiometer with a square-law detector becomes:

$$\frac{\Delta G}{G}[T_A + (F-1)T_0] + T_0\Delta F \ll \Delta T \quad (4)$$

indicating that the accuracy is dependent on receiver gain and noise factor drifts, and that for small values of T_A the simple radiometer is considerably more sensitive to receiver drifts than the Dicke system.]

In practice it is difficult to keep gain drifts below about 0.1 per cent. Thus for a Dicke system using a square-law detector it becomes difficult to measure noise temperature below about 0.3°K when T_0 is 300°K. If it were practical to reduce T_0 to near 0°K, this minimum detectable temperature could be reduced considerably.

Another method for reducing the minimum detectable temperature is as follows: A variable noise source is coupled to one arm of a directional coupler which is inserted between the antenna and attenuator terminals. The coupler is arranged so that the noise introduced by the noise source is coupled into the receiver, and using a well-designed coupler there is negligible change in receiver input impedance or antenna noise power transferred to the receiver. If the noise source is adjusted so that the additional noise temperature coupled into the receiver is fixed at T_0, the system becomes very insensitive to receiver drifts when measuring small values of T_A. By varying the amount of additional noise temperature about T_0 so to keep the receiver output voltage at zero as T_A varies (while recording the amount of noise source variation required to do this) a system similar to that of Machin, Ryle, and Vonberg is obtained except that it is now possible to calibrate values of T_A below room temperature.[3] Here the excess noise temperature of the noise source coupled into the receiver (temperature relative to T_0) is a direct measure of T_A.

The basic problem involved in determining the absolute value of T_A with this modified Dicke system is essentially the same as that with the original Dicke system or any comparison system. It is the problem of determining reference temperatures to an accuracy compatible with the desired radiometer accuracy. This problem appears to be the remaining limitation on absolute measurement of small noise powers.

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[3] K. E. Machin, M. Ryle, and D. D. Vonberg, "The design of an equipment for measuring small radio-frequency noise powers," *Proc. IEE*, vol. 99, part III, pp. 127–134; May, 1952.

Low Frequency Dispersion of ρ and ϵ in Ferrites*

In a recent integrating paper on dielectric properties and conductivity in ferrites, Van Uitert[1] referred to the fundamental work of Koops[2] on Ni/Zn ferrites and his two-layer model. He pointed out—as was formerly suggested by others[3]—the critical dependence on firing temperature of this model and, interpreting the data published by Koops, brought some evidence of a dependence on firing conditions of the thickness of the superficial layer.

We think that this important point requires a more careful examination. If the notations lf and hf are connected respectively with low and high frequency measurements and the notations 1 and 2 with bulk and surface layer of the grain, the ratio x of the layer thickness to the grain diameter is easily obtained from the expressions given by Koops for ρ and ϵ:

$$x = \frac{(\rho_{lf} - \rho_{hf})^2}{\frac{\epsilon_{lf}}{\epsilon_{hf}}\rho_{lf}^2 - \rho_{hf}^2} \qquad \frac{\epsilon_{hf}}{\epsilon_{lf}}\left(1 - \frac{\rho_{hf}}{\rho_{lf}}\right)^2.$$

By plotting against frequency ρ and ϵ experimental data given by him for $Ni_{0.4}Zn_{0.6}Fe_2O_4$ at various sintering atmospheres and maximum sintering temperatures, and by extrapolating these curves for low and high frequencies, ρ and ϵ values are obtained. Taking an average grain diameter of 1 micron and a bulk permittivity ϵ_{bf} of the order of 20, the thickness is given by Table I.

TABLE I

Sintering at 1300°C	Cooling	Per cent Fe^{2+} after sintering	Thickness in angströms
air	fast in air	0.42	1.0
oxygen	fast in air	0.38	5.4
air	slow in air	0.07	20
oxygen	slow in oxygen	0.1	32

The thickness values give evidence of two different oxidation mechanisms. The two first data (some angströms) are in good agreement with the idea of oxygen chemisorption during cooling, more important, of course, in oxygen than in air, but which affects only the surface of crystals. The thickness found for the two other data, ten times larger, suggests on the other hand a more complete oxidation mechanism, with an important decrease of the concentration in the ferrous ions formed during the firing at 1300°C.

In 1955 we studied the occurrence of this second mechanism in hematite and in Mn/Zn ferrite and considered the hypothesis of the existence of an interstitial lattice of oxygen ions on a thickness of several crystalline cells. Its formation, by diffusion from the chemisorbed layer, would require, of course, a high number of defects in the crystals and would give, therefore, a good account of the dependence on the maximum firing temperature and the cooling conditions. As a matter of fact, the curves resistivity vs firing temperature gave us a lot of information about the grain structure of the ceramic material.

We thought that structure-sensitive phenomena like valency induction and ferrimagnetism itself must be suppressed by the second mechanism. We were able to verify this point of view on hematite and on Mn/Zn ferrite and could understand a lot of formerly unexplained facts about thermistor materials and high permeability ferrites. We were surprised to find among the consequences of this oxidation mechanism the large time decrease of permeability reported by Snoek for the Mn/Zn ferrite.[4]

We already mentioned, in connection with Van Uitert's former work[5] that minor additions could prevent the formation of such oxidized layers.[6]

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* Received by the IRE, December 10, 1956.

[1] L. G. Van Uitert, "Dielectric properties of and conductivity in ferrites," Proc. IRE, vol. 44, pp. 1294–1303; October, 1956.

[2] G. C. Koops, "On the dispersion of resistivity and dielectric constant of some semiconductors at audio frequencies," *Phys. Rev.*, vol. 83, pp. 121–125; July, 1951.

[3] L. C. F. Blackman and N. P. R. Sherby, "Note on an investigation of the anomalous time-constant of certain iron deficient magnesium manganese ferrites," *J. Electronic (Gr. Brit.)*, vol. 1, pp. 385–388; January, 1956.

[4] J. P. Suchet, "Structures granulaires à couche superficielle dans les céramiques à base d'oxyde de fer," *J. Phys. Radium*, to be published.

[5] L. G. Van Uitert, "High resistivity nickel ferrites. The effect of minor additions of Mn or Co," *J. Chem. Phys.*, vol. 24, pp. 306–314; February, 1956.

[6] J. P. Suchet, "Effect of minor additions on the resistivity of ferrites," *J. Chem. Phys.*, vol. 25, p. 368; August, 1956.

Graphical Method of Determining the Efficiency of Two-Port Networks*

In a recent contribution to this column it was shown[1] how a method, introduced by Altschuler,[2] for finding the maximum efficiency of an arbitrary two-port network, which is terminated in its conjugate-image impedance match, could be given a simple geometric explanation. We shall now show how the efficiency of a two-port network, terminated in an arbitrary load, can be obtained by similar graphical constructions.

The common method in analyzing a two-port network is to perform three measurements (immittance or reflection-coefficient measurements), having the output terminated in pure reactances. If we assume that the complex impedance plane is stereographically mapped on the unit sphere (Fig. 1), three points on the great circle in the yz-plane are transformed into three points on the right hemisphere. Through the latter points a circle, the image circle of the great circle, can be drawn.

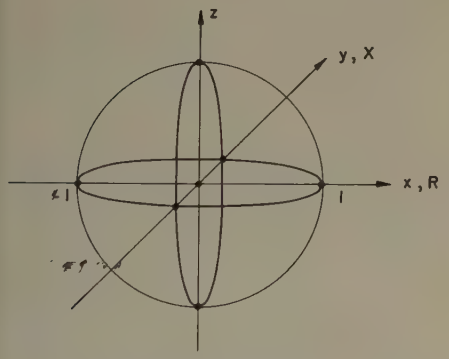


Fig. 1—The unit sphere.

First, the image circle is moved until it is symmetric with both the xz plane and the xy plane. This can be done in two steps, each corresponding to a lossless network. In the first step, the image circle is transformed so that it is symmetric with the xz plane. Several methods are possible, the simplest being the ones of Weissfloch[3] and Wheeler-Dettinger.[4] Weissfloch extracts a series reactance, corresponding to a parabolic transformation that has its fixed point at the top of the sphere; Wheeler-Dettinger extracts a piece of uniform transmission line, corresponding to an elliptic transformation that has its axis of rotation coalescing with the x axis. In Fig. 2 the transformed image circle is shown in the xz plane as a straight line C. The symmetry to the xy plane is now easily obtained by a hyperbolic transformation along the z axis; this corresponds to an ideal transformer. The projection C is transformed into C' (see Fig. 2).

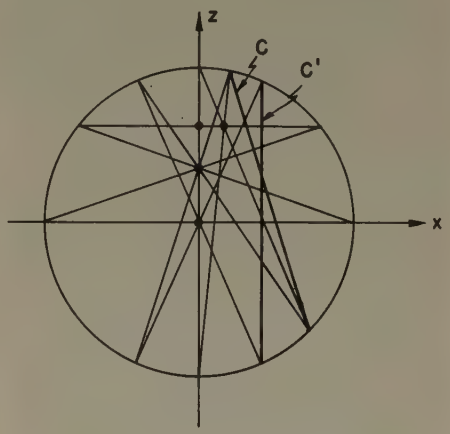


Fig. 2—Graphical construction $C \rightarrow C'$, which corresponds to an ideal transformer.

In a basic research work, Deschamps[5] has shown that the efficiency of a two-port network can be expressed as the ratio of two "pseudo distances" from a point P on the sphere to two circles C_1 and C_2. This ratio is invariant by inversion; therefore it is not influenced by transformations like the ones already performed above. In Fig. 3 we interpret the circle C_1 as C' and C_2 as the great circle in the yz plane. An arbitrary load will, after transformation through the network, correspond to a point on the sphere to the right of C'. For simplicity, let us select the point P shown in Fig. 3. Using the notations

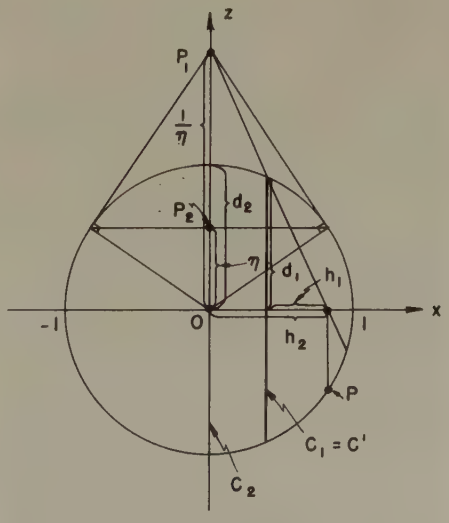


Fig. 3—Graphical determination of the efficiency η.

of the figure, we can write the efficiency η of the two-port network:

$$\eta = \frac{h_1}{d_1} \cdot \frac{d_2}{h_2}, \tag{1}$$

where $d_2 = 1$, because it is the radius of the unit circle. The use of similar triangles immediately yields a distance $OP_1 = 1/\eta$ on the z-axis. The polar to P_1 cuts the z axis at P_2, so that $OP_2 = \eta$. Fig. 4 shows a simple construction for obtaining P_2 without any constructions outside the unit circle.

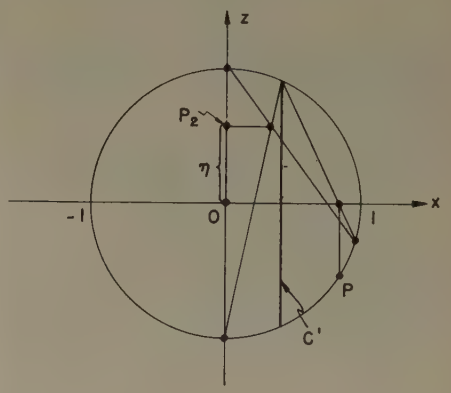


Fig. 4—Graphical determination of the efficiency η.

It is interesting to check that if the point P is situated in $(1, 0)$, $\eta = \eta_{max}$; this is evident from Fig. 5. P_2 is simply the crossover point between the z axis and a line joining $(-1, 0)$ and the upper point of C'. Therefore

$$\eta = \eta_{max} = \frac{h_1}{d_1}. \tag{2}$$

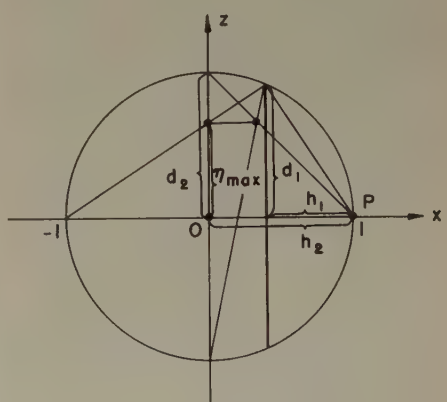


Fig. 5—Graphical determination of the maximum efficiency η_{max}.

The yz plane contains the complex reflection coefficient plane. Fig. 5 reveals that η_{max} is the radius of a circle which is C' stereographically mapped on the yz plane from the point $(-1, 0)$. This checks nicely with Wheeler and Dettinger.[4]

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This work was supported in part by the Army (Signal Corps), the Air Force (Office of Scientific Research, Air Research and Development Command), and the Navy (Office of Naval Research).

[1] E. F. Bolinder, "Maximum efficiency of four-terminal networks," Proc. IRE, vol. 44, p. 941; July, 1956.

[2] H. M. Altschuler, "Maximum efficiency of four-terminal networks," Proc. IRE, vol. 43, p. 1016; August, 1955.

[3] A. Weissfloch, "Die wirkleistungsverluste in linearen vierpolen in abhängigkeit vom wert des transformierten scheinwiderstandes," *E.N.T.*, vol. 19, pp. 259–265; December, 1942.

[4] H. A. Wheeler and D. Dettinger, "Measuring the Efficiency of a Superheterodyne Converter by the Input Impedance Circle Diagram," Wheeler Monograph No. 9, March, 1949.

[5] G. A. Deschamps, "Geometric viewpoints in the representation of wave guides and waveguide junctions," *Proc. Symposium on Modern Network Synthesis*, Polytech. Inst. of Bklyn., pp. 277–295; April, 1952.

TV Sweep Generation with Resonant Networks and Lines*

The principal object of this communication is to extend the discussion in the above article by Schlesinger.[1] At the same time we wish to direct the attention of the reader to a correction of the appendix of the same article.

Eq. (14) of the appendix of Schlesinger's article gives as the error squared

$$G = \int_{\tau/2}^{H-(\tau/2)} \left[f(t) - \sum_{n=1}^{N} a_n \sin(n\omega t) \right]^2 dt. \quad (14)$$

G becomes an "extremum," if all the $\delta G/\delta a_k$ vanish where k runs from 1 to N. Recognizing that n is a dummy index of summation in (14) we obtain

$$\partial G/\partial a_k = \int_{\tau/2}^{H-(\tau/2)} 2 \left[f(t) - \sum_{n=1}^{N} a_n \sin(n\omega t) \right] \cdot \sin(k\omega t) dt$$

which results in a system of simultaneous equations of the form

$$\sum_{n=1}^{N} A_{kn} a_n = \int_{\tau/2}^{H-(\tau/2)} f(t) \sin(k\omega t) dt, \qquad (k = 1, 2, \cdots N)$$

where

$$A_{kn} = \int_{\tau/2}^{H-(\tau/2)} \sin(n\omega t) \sin(k\omega t) dt, \qquad (k, n = 1, 2, \cdots N).$$

Since the functions $\sin(k\omega t)$ are not orthogonal over the interval of integration, the matrix A_{kn} is not a diagonal one and Schlesinger's (15) and (16) and Tables I and II are incorrect. The error in (15) is further illustrated by the example $f(t) = \sin \omega t$, and by noting that in Fig. 3 of Schlesinger's article the modified approximation has a larger error over the reduced interval than that of the normal approximation. (At 20° the respective errors are 40 per cent and 22 per cent.)

Referring to the resonant type of sweep Dr. Schlesinger concludes that " . . . it can meet but not beat the performance standards set by the power feedback type of circuits now in use." By paying attention to the details of design a relatively simple resonant type of circuit will yield greatly improved performance from the standpoint of circuit efficiency without any sacrifice of retrace or linearity characteristics.

I have had a resonant type of sweep in operation since 1950. The circuit shown in Fig. 1 employs a 6AU5GT driver and a 6W4GT diode to deflect a 70° tube at 15 kv anode voltage. The total input to the circuit is 30 ma at 360 v; *i.e.*, an input power of 11 watts; in addition to the sweep, screen supply and high voltage are obtained as outputs. This high efficiency is obtained by the addition of two inductances and capacitors to the conventional circuit. It may be mentioned that the 6AU5GT has seen about 6000 hours of service.

* Received by the IRE, July 3, 1956.

[1] K. Schlesinger, PROC. IRE, vol. 44, pp. 768–775; June, 1956.

It does not seem that ac-dc conversion efficiency should be defined as the ratio of $(\frac{1}{2}LI^2f)$ over power input, because the expression $(\frac{1}{2}LI^2)$ is merely the peak energy stored in the yoke, whereas the true value of the circulated volt-amperes is the summation of the products of the frequency components of yoke voltage and current; this will be approximately $(\frac{1}{2}LI^2f)$. Of course, the actual power dissipated in the yoke depends upon the yoke losses at the various harmonics of sweep frequency. In the conventional circuit the reactive power is handled by the driver and diode; the tube losses will be roughly proportional to the square of the current components of the yoke, and it may be observed that 72.5 per cent of this loss is included in the fundamental and 89 per cent in the fundamental and second harmonic. In an efficient resonant type of sweep circuit, employing resonance at fundamental and second harmonic, the tube losses at these frequencies may be eliminated, so that if the higher harmonic components of current *are not seriously increased*, the tube dissipation may be reduced to 11 per cent of its normal value. The principal losses will then be those in the yoke, the transformer, and the reactive elements which are added to the circuit.

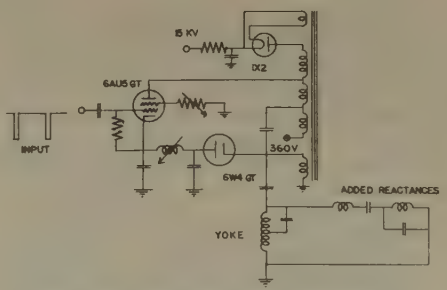


Fig. 1—Practical resonant sweep deflection circuit.

While the proper admittance may be realized in the form of a (nonuniform) transmission line which resonates the yoke at the sweep frequency and many of its harmonics, the proper admittance function should be determined from the condition that the higher order harmonic power not be increased.

The determination of the admittance function will be explained by reference to Fig. 2. Fig. 2(b) and 2(c) shows the yoke voltage and current. Vacuum tubes are employed to control the yoke voltage during the trace portion of the cycle; during the retrace portion, the vacuum tubes are open circuits. Fig. 2(d) and 2(e) shows the currents which would flow in L_1 and L_2 if they are respectively series tuned to frequencies equal to the reciprocal of the trace period and twice the reciprocal of the trace period. The magnitudes of I_1 and I_2 may be controlled by the magnitudes of L_1 and L_2, so that with a proper choice (based upon Fourier's series) the sum current is a minimum in rms value and is shown in Fig. 2(f). The vacuum tube current is shown in Fig. 2(g).

For the details of design we refer again to Fig. 2. Let the sweep period be 2π and the retrace period be $2b$ so that the trace period is $2(\pi - b)$. We shall write the yoke voltage as

$$E = \cos \omega t \qquad -b < t < b$$
$$E = \cos \omega b \qquad b < t < 2\pi - b. \quad (1)$$

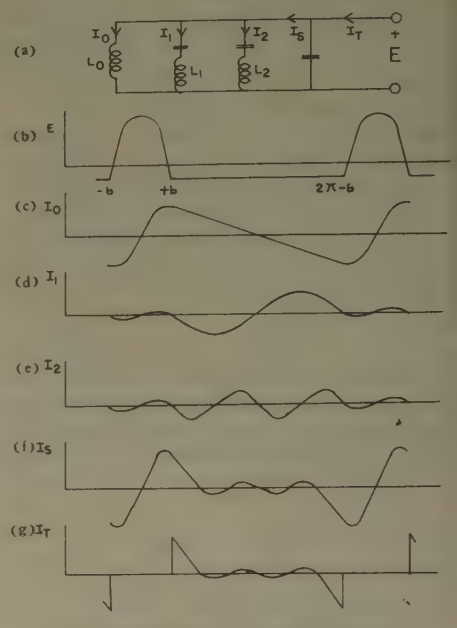


Fig. 2—Determination of correct admittance function.

Since the integral of the yoke voltage over one full period must vanish we have the relation

$$\tan \omega b = -\omega(\pi - b). \quad (2)$$

If the yoke voltage is impressed across a unit inductance in series with a capacitor equal to $(1/\alpha)^2$, the current in the inductance is a solution of the differential equation

$$(p^2 + \alpha^2) I = pE \quad (3)$$

where p denotes differentiation with respect to time. Because of the differential equation and the continuity of the impressed voltage the current and its first derivative are both continuous. We choose α so that

$$\alpha(\pi - b) = k\pi \quad (4)$$

where k is an integer. As a result of (3) and (4) and the conditions of continuity, the current is

$$I = \frac{\omega}{\omega^2 - \alpha^2} \left[\sin \omega t - \frac{\sin \omega b}{\sin \alpha b} \sin \alpha t \right] \qquad -b < t < b$$
$$I = A \sin \alpha(t - \pi) \qquad b < t < 2\pi - b \quad (5)$$

where

$$(-1) A\alpha = \frac{\omega}{\omega^2 - \alpha^2} [\omega \cos \omega b - \alpha \sin \omega b \cot \alpha b]. \quad (6)$$

Reference to (2) permits one to write

$$(-1)^k A = \frac{\omega^2}{\omega^2 - \alpha^2} (1 + k\pi \cot \alpha b) \cos \omega b. \quad (7)$$

The yoke current in a unit inductance during the trace period is $(\pi - t) \cos \omega b$, and since A is the magnitude of the current in L_k, the proper value of L_k is

$$L_k = \frac{\omega^2}{2(\omega^2 - \alpha^2)}(1 + k\pi \cot \alpha b) L_0,$$

$$\alpha = \frac{k\pi}{\pi - b} \tag{8}$$

where L_0 is the yoke inductance. The capacitances are determined from

$$C_k = 1/\alpha^2 L_k. \tag{9}$$

By elementary synthesis other equivalent circuit configurations may now be derived which have a more convenient practical form.

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Author's Comment[2]

In this author's opinion, Mr. Wagner's letter does not invalidate any of the statements made in the paper.

1) The set of coefficients derived by (16) in the appendix of the paper, is plotted graphically in curve (b) of Fig. 3. This curve approaches the ideal sawtooth wave 3 times better in the sweep-interval ($40° \leqq \phi \leqq 320°$), than does the conventional Fourier series, graph (a) in Fig. 3. The interval $-40° < \phi < +40°$, where curve (b) is twice as much in error as curve (a), is not sweeptime, but flyback-time. This is so stated on page 770, lines 5–8. of the paper. By citing this statement in reverse, as he does, Mr. Wagner makes a supporting evidence look like a discrepancy.

2) The expression $\frac{1}{2}LI^2$ for circulating energy, as used in the paper, is a logical choice, since it can be measured readily and is independent of waveform. Both advantages are lost if this expression is replaced by the sum of sideband energies, as suggested by Wagner. Besides, the end result of his summation is in error by an order of magnitude.

3) The circuit shown in Wagner's Fig. 1 does not belong in the group of circuits for "synthetic sweep," as discussed in the paper. Rather, his is a conventional power feedback circuit, with the "booster diode" shifted from the plate return to the cathode return.

In operation, Wagner's circuit will: a) stop output as soon as trigger pulses stop; b) deliver an approximate sawtooth-output, even with the reactance network disconnected.

Both performance features are the opposite of the typical behavior of sweep forming networks, as shown in Figs. 6 and 12 of the paper. None of the circuits shown there uses power feedback. Note that power-recovery by a booster-diode, and power-storage and recirculation in a resonant network, are two basically different approaches to the problem. The first is inherently a "one-shot" system; the second is a "ringing" system. Both methods are mutually exclusive!

Wagner's circuit is a hybrid between the two, trying to combine the advantages of both. However, it has been the writers experience that the introduction of power-feedback into resonant sweep causes the network Q to drop at a rate which largely offsets the booster gain. Conversely, the addition of a sweep-forming network to a well-designed power feedback circuit may do more harm than good, since the network only adds its own losses to the system, without the returns from resonance.

A glance at Wagner's Fig. 2 confirms the suspicion that his network is heavily damped. His branch-currents I_1 and I_2 have lost all resemblance to pure harmonics. It requires some courage to try to analyze that situation!

Of course, this test cannot be used to prove or disprove my analysis of synthetic sweep, since there is no basis for comparison.

Specifically, I can see why the retrace in Wagner's circuit is as fast as that of a conventional switching circuit, and not as slow as would follow from my Fig. 2, for a two-pole resonant network. His network cannot "flywheel," since it is gated after each cycle.

Mr. Wagner's contention, that only two harmonics are enough to build a good sawtooth, is without any foundation in theory or practice. This may happen with distorted current components as shown in his Fig. 2. Such complex waveforms are, indeed, unusually accommodating at times.

But if Wagner ever tried to synthetize a saw from pure sinewaves, and had only the first two terms to work with, then I am sure that he would soon find himself in complete agreement with all statements made in my paper.

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Received by the IRE, August 29, 1956.

Letter from Mr. White[3]

The recent paper by Schlesinger[1] on resonant networks for sweep circuits was of especial interest inasmuch as a somewhat similar investigation some years ago indicated that remarkably good sweep waveforms could be synthesized from a finite number of harmonic components. Although this study never reached the experimental stage due to practical difficulties associated with the problem at hand, the results are presented here in the hope that they may be of interest to others wishing to pursue the subject further.

The modified Fourier series used by Schlesinger exhibits a kind of Gibbs' phenomenon which is typical of applications where a discontinuous function is approximated by a finite number of Fourier components. For example, it may be noted that the waveform of Fig. 3 of Schlesinger's paper has a peak slope variation of about 50 per cent whereas when the number of harmonics is increased from 4 to 8 as in Fig. 4 of Schlesinger's paper, the peak slope error is reduced only to about 38 per cent. To one whose primary interest is the minimizing of slope errors, these figures may be discouraging. As will be shown, however, using a different technique to determine the harmonic amplitudes permits one to synthesize sweep waveforms with the slope errors held to a specified tolerance.

Consider the time function

$$f(t) = T_{2r}\left[\frac{\cos\frac{\omega t}{2}}{\cos\frac{\omega\tau}{2}}\right]$$

where

$T_n(x)$ is the nth order Tchebycheff polynomial
τ = constant = $\frac{1}{2}$ the allowed total retrace time
$\omega = 2\pi \times$ the desired sweep repetition rate.

It is apparent that $f(t)$ is a polynomial in even powers of $\cos \omega t/2$ and that if we make use of the relation

$$\left\{\cos\left(\frac{\omega t}{2}\right)\right\}^{2s}$$

$$= \frac{1}{2^{2s}}\left[\frac{(2s)!}{(s!)^2} + 2\sum_{k=1}^{s}\frac{(2s)!}{(s+k)!(s-k)!}\cos(k\omega t)\right]$$

then $f(t)$ can be expressed as a harmonic series in the form

$$f(t) = \bar{f} + \sum_{k=1}^{r} f_k \cos(k\omega t).$$

From the properties of the Tchebycheff polynomial, we may also deduce that

$$|f(t)| \leqq 1 \text{ when } \left|\cos\left(\frac{\omega t}{2}\right)\right| \leqq \cos\left(\frac{\omega\tau}{2}\right)$$

and

$$|f(t)| \geqq 1 \text{ when } \left|\cos\left(\frac{\omega t}{2}\right)\right| \geqq \cos\left(\frac{\omega\tau}{2}\right).$$

These properties are illustrated in Fig. 1

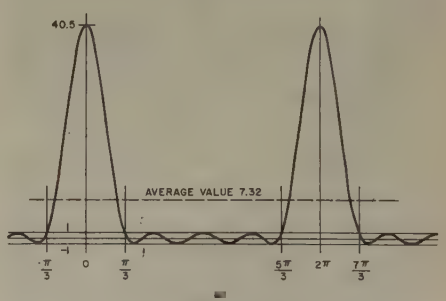


Fig. 1—The function $f(t)$: 4 harmonics, $\omega\tau = \pi/3$.

which is a plot of $f(t)$ for the case where $r = 4$ and $\omega\tau = \pi/3$.

Suppose now that we form the function

$$g(t) = \int_0^t \left\{\frac{f(t) - \bar{f}}{\bar{f}}\right\} d(\omega t) = \sum_1^r \frac{f_k \sin(k\omega t)}{k\bar{f}}$$

Received by the IRE, September 11, 1956

$g(t)$ will be characterized by a steeply rising slope during the intervals $-\tau<t<\tau$ and an approximately uniform declining slope during the interval $\tau<t<(2\pi/\omega)-\tau$. The limits of variation of this slope are given by the relation

$$1-\frac{1}{\bar{f}} \leqq -\left\{\frac{d}{d(\omega t)}g(t)\right\} \leqq 1+\frac{1}{\bar{f}}$$

or, in other words, the fractional variation in slope is $1/\bar{f}$. In Fig. 2, we have plotted both

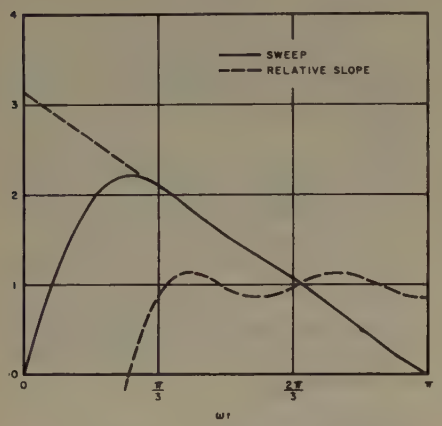


Fig. 2—The function $g(t)$ and its relative slope: 4 harmonics, $\omega\tau=\pi/3$.

$g(t)$ and its slope function for the four harmonic case where $\omega\tau=\pi/3$. The relation between maximum slope error, allowable retrace time, and the number of harmonics required is shown in Fig. 3. This is a plot of $1/\bar{f}$ vs $\omega\tau$ for the cases of 2, 4, 6, or 8 harmonics.

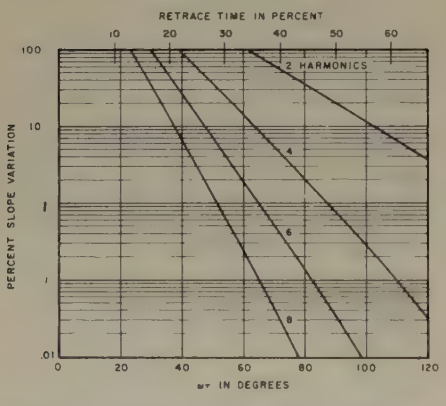


Fig. 3—Slope variation as a function of retrace time.

Fig. 4 shows the slope error for two cases which are roughly equivalent to the ones computed by Schlesinger. Curve no. 1 is the slope error for 4 harmonics and $\omega\tau=53.3°$. It will be noted that the peak slope error is 25 per cent and that the duty cycle between waveform peaks, *i.e.*, between points where the slope is zero, is 77 per cent. This corresponds with Schlesinger's curve which gives about 50 per cent slope error over the same duty cycle. Curve no. 2 of the same figure is the slope error for 8 harmonics and $\omega\tau=37°$. This curve gives a maximum slope

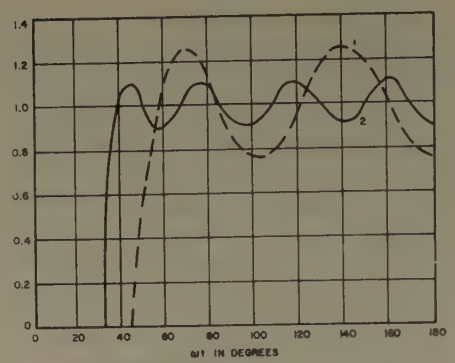


Fig. 4—Slope variation curves: curve 1, 4 harmonics, $\omega\tau=53.3°$; curve 2, 8 harmonics, $\omega\tau=37°$.

error of 10 per cent and a duty cycle between waveform peaks of about 83 per cent. This corresponds to Schlesinger's result for 8 harmonics which gave 38 per cent slope error with the same duty cycle.

From the oscilloscope photographs, it is apparent that Schlesinger in his experimental tests was obtaining better performance than his theory indicated. It is probable that the actual harmonic amplitudes were closer to the Tchebycheff values than to the Fourier values.

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Author's Comment[4]

The correspondence by Mr. White is a valuable contribution to the problem of synthetic sweep. It is of particular interest that there seems to be general agreement between the Tchebycheff and the Fourier approach in evaluating retrace speed as a function of bandwidth. This point, as well as power efficiency, has been more of a problem, in our experimental work, than sweep linearity, which was generally satisfactory.

There may be room for two additional comments:

1) In the display of stationary television pictures, it appears that positional errors are more readily detected than slope errors of equal magnitude. Assuming, for example, a sinusoidal velocity modulation of $\pm\rho_s$ per cent with N cycles per scan. The resulting positional error is $\rho_s=\rho_v/2\pi N$, where $\rho_s=\Delta x/W$, and W the picture width. Hence, short ripples on the slope-curve may pass unnoticed in the display. This seems to be borne out by the photographs 7(b), 13(a), and 15(b) of the paper where small oscillations, discernible on the yoke-voltage wave, do not seem to appear on the sweep wave. For the same reason, the improvement in sweep linearity between Figs. 3(a) and 4 is better than the slope error reduction would indicate, because the "wavelength" of the slope function 4(b) has decreased over Fig. 3 in the process of doubling N.

2) In comparing theory with experience, it may be worth mentioning that all practical circuits for resonant sweep, as reported in the paper, used shock excited harmonics, rather than continuous waves. As a result, the amplitude of the Kth harmonic decreased slightly during each scan, since $K-1$ cycles are ringing without external power supply. In the network of Fig. 6, for instance, a loss of 1.3 db per trace was observed for the 6th harmonic.

As a result, the spectral distribution varied slightly during a line scan, with a resultant small nonsymmetry discernible in Figs. 7 and 13. This is in violation of any theory dealing with synthesis from cw components. Hence, in order to study the merit of different spectra more accurately, it may be of interest to repeat the above tests with equipment using N oscillators locked to line-sync, as sources for harmonic energy.

K. SCHLESINGER

[4] Received by the IRE, October 5, 1956.

Simplification of Field Strength Computations for Shielded Enclosures*

The method developed by Haber[1] has made possible a considerable increase in the accuracy of sensitivity measurements on aircraft adf loop antennas in screen rooms, but the computations involved in arriving at the field strength become quite tedious. The following derivation results in a simplified formula allowing direct computation of the relation between the voltage output of the signal generator used to feed the transmission line, and the field strength in volts per meter at the loop. This relation, having the dimension of length, and usually referred to as the "attenuation constant" or "room factor" (K_d), is particularly useful in making sensitivity measurements as required by RTCA specifications, where acceptance criteria are based on the field strength necessary to obtain the desired performance.

Haber's original equation is

$$H_{\text{total}}=\frac{I}{w}\left[\frac{\sinh\alpha}{\cosh\beta-\cosh\alpha}-\frac{\sinh 2\alpha}{\cosh 2\beta-\cosh 2\alpha}+4\sinh\alpha\cosh\beta\exp(-2\gamma)\right]. \quad (1)$$

This expression may be transformed by applying standard hyperbolic identities into

$$H_{\text{total}}=\frac{I}{w}\sinh\alpha\cosh\beta$$

* Received by the IRE, August 3, 1956; revised manuscript received, October 15, 1956.

[1] F. Haber, "Generation of standard fields in shielded enclosures," PROC. IRE, vol. 42, pp. 1693–1698; November, 1954.

$$\cdot\left[\frac{1}{(\cosh\beta+\cosh\alpha)(\cosh\beta-\cosh\alpha)} + 4\exp(-2\gamma)\right]. \quad (2)$$

This reduction gives an expression requiring the use of only three hyperbolic functions instead of six, with a quite appreciable saving in time and tempers when several computations are needed in quick succession.

As defined above, $K_d=E_L/E_{v/m}$, where E_L is the signal generator output voltage, and $E_{v/m}$ is the field strength at the loop in volts per meter. Since $E_{v/m}=H_{\text{total}}Z_0$, and $E_L=IZ_L$, Z_0 being 120π ohms, the impedance of free space, and Z_L the line terminating resistance, the final expression for K_d becomes

$$\frac{1}{K_d}=\frac{14842\sinh\alpha\cosh\beta}{Z_L w}\cdot\left[\frac{1}{(\cosh\beta-\cosh\alpha)(\cosh\beta+\cosh\alpha)} + 4\exp(-2\gamma)\right]. \quad (3)$$

The constant includes the conversion factor necessary to permit the use of the enclosure dimensions in inches.

This expression has been found convenient in the computation of room factors for a variety of screen rooms, and the sensitivity measurements obtained have shown much better agreement than those obtained with factors computed from older formulas.

It should also be noted that when operating at the low and medium adf frequencies (below 2 mc) in a screen room of average size (10–15 feet long), the transmission line length is small compared to the wavelength, and a considerable mismatch can be tolerated without seriously disturbing the field. Under these circumstances, adjustment of the room factor to a convenient value can often be made by changing the terminating resistance (Z_L) on the line without changing any other dimensions.

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A Comparison of Two Radiometer Circuits*

Letter from Mr. Tucker

I feel that the above paper,[1] although interesting and valuable, fails to discuss several important points which are essential to a full understanding.

1) On examining the working for the Dicke system it becomes clear that the following assumptions are made which are not stated in the list of assumptions nor in the conclusion, although they are vital to the interpretation of the results:

$$\left.\begin{matrix}\alpha \gg\beta\\ \alpha\gg q\end{matrix}\right\}\text{explicit assumptions}$$

$\beta\ll q$: an implicit assumption, left to the reader to puzzle out for himself.

The last assumption is implied by the author's approximation

$$P_2=[G_{13}(q)+G_{14}(q)]\beta.$$

In the working for the two-receiver system, the assumption that $\gamma\ll\alpha$ is implicit, but is not stated.

These assumptions are made only for the simplification of the analysis, and are not necessary for the physical realization of the systems, which would work perfectly well with a nearly sinusoidal input and $\alpha\ll\beta$, $\alpha\ll\gamma$, $q\ll\beta$. The conditions which *are* necessary for successful realization are not stated, but I think that in the Dicke system one is $\gamma<2q$, and in the two-receiver system one is $\gamma<2(f_1-\alpha)$. The two-receiver system is actually easily analyzed without any restriction other than $\gamma<2(f_1-\alpha)$,[2] and a recent paper of mine[3] shows that when there is no low-pass filter other than the one required to eliminate the sum frequencies from $2(f_1-\alpha)$ upwards, then the output signal /noise power ratio is

$$\left(\frac{s}{n}\right)_0=2\frac{\sigma_s^4}{\sigma_n^4}$$

in the author's terminology. The effect of the low-pass filter is easily allowed for, remembering that the output spectrum is triangular; thus there is no effect at all until γ is reduced below α, and then

$$\left(\frac{s}{n}\right)_0=2\frac{\sigma_s^4}{\sigma_n^4}\cdot\frac{\alpha^2}{\gamma(2\alpha-\gamma)}$$

and if $\gamma\ll\alpha$, this reduces to

$$\left(\frac{s}{n}\right)_0=\frac{\sigma_s^4}{\sigma_n^4}\cdot\frac{\alpha}{\gamma}$$

as obtained by the author.

2) In view of the approximations made, the statement of the improvement of the two-receiver system over the Dicke system to three significant figures (*i.e.*, 3.48) needs qualification.

3) The paper is concerned only with background noise arising in the receiving amplifier. If the noise arises (as in many practical applications, especially when the radiation being measured is acoustic and not electromagnetic) in the medium of propagation or in the receiver (*e.g.*, antenna) before the modulator, then the analysis of the two-receiver system is still valid; but that of the Dicke system is *not* valid, since this system was intended only to overcome amplifier noise.

4) It is concluded that the two-receiver system can detect a signal at a level 3.5 times lower than the Dicke system can. But, surely, if the two available receivers (*e.g.*, antennas) were merely joined in parallel and then applied to the Dicke system in place of the one receiver assumed in the paper, then the Dicke system would be improved by the doubling of signal power, and would be inferior to the other system by a factor of only 1.7.

5) It is not mentioned that the signals at the two receivers (*e.g.*, antennas) are fully correlated only if the line joining the two receivers is parallel to the signal wavefront. In typical applications there is smooth and continuous relative movement between the source of radiation (whether terrestrial or extraterrestrial) and the receiving system, as produced, for example, by the rotation of the earth, carrying the receivers, relative to a source of radiation such as a radio star. In fact such movement is usually essential to efficient detection of the signal. In such a case, the signal inputs of the two-receiver system are fully correlated only at one position, and the "dc" output, which traces the cross-correlation function of the two receiver inputs, is actually quasi-sinusoidal at a very low frequency of say γ_0 over a number of cycles which depends on the bandwidth of the receivers. It is clear, then, that there is a fairly definite lower limit to the low-pass cutoff frequency; when the filter has a rectangular band-response this limit is clearly γ_0 approximately, and this cutoff gives the lowest attainable value of just-detectable signal. This limitation does not apply to the single-receiver system, where the lowest value of the cutoff frequency (γ) is limited only by the time during which the signal is being received at all.

6) The assumption of a rectangular low-pass filter response is rather unrealistic, as in many practical cases the integration time required is very large, and RC-type networks have to be used. Using the results of a calculation by Griffiths[4] on the optimum use of RC networks for separating signal from noise, and assuming a quasi-sinusoidal output signal as described above, I have calculated the effect of replacing the filter in the two-receiver system by N simple resistance-capacitance circuits in independent cascade (*i.e.*, separated from one another by an amplifier or attenuator); and on the assumption that the frequency of 3-db attenuation (γ_1) of a single RC section is very small compared with α, the optimum condition for detection is

$$\frac{\gamma_1}{\gamma_0}=\sqrt{2N-1}.$$

Without this condition, the output signal/noise power ratio is

* Received by the IRE, January 9, 1956.

[1] S. J. Goldstein, Jr., Proc. IRE, vol. 43, pp. 1663–1666; November, 1955.

[2] At this stage the reader should be reminded that the two-receiver system merely multiplies together the two input signals and then smooths the product with a low-pass filter. The input bandwidth for signal and noise is α, the center frequency of the band is f_1 and the cutoff frequency of the low-pass filter is γ. The input signal amplitude is σ_s and the input rms noise amplitude is σ_n.

[3] D. G. Tucker, "Signal/Noise Performance of Multiplier (or Correlation) and Addition (or Integrating) Types of Detector," IEE Monograph No. 120R, London, England; 1955.

[4] J. W. R. Griffiths, "Optimum rc filters for separating sinusoidal signal from noise," *Wireless Engr.*, vol. 33, pp. 268–270; November, 1956.

$$\left(\frac{s}{n}\right)_0 = \frac{\sigma_s^4}{\sigma_n^4}\cdot\frac{\alpha}{K\gamma_1\left[1+\frac{\gamma_0^2}{\gamma_1^2}\right]^N}$$

where

$$K = \frac{\pi}{2}\cdot\frac{[2N-1]!}{2^{2(N-1)}[N-1)!]^2}.$$

On putting in the optimum condition, the maximum output ratio becomes

$$\left(\frac{s}{n}\right)_{opt} = \frac{1}{K^1}\cdot\frac{\sigma_s^4}{\sigma_n^4}\cdot\frac{\alpha}{\gamma_0}$$

where

$$K^1 = \frac{\pi\sqrt{2N-1}\cdot[2(N-1)]!}{\left(1-\frac{1}{2N}\right)^N\cdot 2^{2N-1}[(N-1)!]^2}$$

so that for an output signal/noise ratio of unity (as required by the author for the least-detectable signal power σ_{1d}^2) we have

$$\sigma_{1d}^2 = \sigma_n^2\sqrt{\frac{K^1\gamma_0}{\alpha}}.$$

Note that when

$$n=\infty, \quad K^1 = 1/0.51 \simeq 2$$
$$n=2, \quad K^1 = 1/0.41 \simeq 2.5$$
$$n=1, \quad K^1 = \pi.$$

Thus a single RC circuit gives a least-detectable signal 2.5 db higher than the author's ideal filter gives.

7) Finally, there appear to be several misprints. At the bottom of the left-hand column on p. 1666, the equation for $R_{11}(\tau)$ should read

$$R_{11}(\tau) = k^2\sigma_s^4.$$

The lower limit of integration in the first equation after Fig. 2 should be $q-\beta/2$. In the right-hand column on p. 1665, about a third of the way down, $k^2/16\sigma_s^4$ should read $(k^2/16)\sigma_s^4$.

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Letter from Mr. Graham[5]

In Mr. Goldstein's paper a calculation is made of the least detectable signal power in the input of a Dicke radiometer as

$$\sigma_{1d}^2 = 4\sqrt{2}\sigma_n^2\sqrt{\frac{\gamma}{\alpha}}$$

under the conditions of an input modulator which multiplies by $\frac{1}{2}(1+\sin 2\pi qt)$ and a demodulator which multiplies by $\sin 2\pi qt$. If both are replaced by square-wave multiplication (*i.e.*, multiply by $+1$ for $0<2\pi qt<\pi$ and by -1 for $\pi<2\pi qt<2\pi$) the signal output power increases by a factor of 4, to give

$$\sigma_{1d}^2 = \sqrt{2}\sigma_n^2\sqrt{\frac{\gamma}{\alpha}}.$$

The expression for the least detectable signal in the two-receiver radiometer $\sigma_{1d}^2=\sigma_n^2\sqrt{\gamma/\alpha}$ applies to the signal in only one antenna. Any comparison of the two systems should be made on the basis of the total signal input, which is just twice this. Hence

$$\sigma_{1d}^2 = 2\sigma_n^2\sqrt{\frac{\gamma}{\alpha}}.$$

This indicates that Dicke system as modified above is $\sqrt{2}$, or 1.5 db better than the two-receiver system, since the two separate antennas could be duplexed to feed their combined signals into the input of the Dicke system. The modified Dicke system requires a simpler demodulator than in the original Dicke system or in the two-receiver system, and uses a less complex input and heterodyner than the two-receiver system. The square wave input modulation may be accomplished practically in low frequency applications (as resistance thermometers) with a reversing switch. Microwave applications would require a switched section of $\frac{1}{2}$ wavelength line or waveguide for effectively reversing the polarity of the input signal.

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Received by the IRE, January 20, 1956.

Author's Comment[6]

Graham and Tucker have correctly pointed out that the formula which gives the least detectable signal power for the two-receiver radiometer should contain a factor of 2, in order to refer to the total signal power needed to produce an output signal to noise ratio of unity. This will give a realistic comparison with other radiometers in many cases. However, when the two-receiver radiometer is used in an interferometer, the two antennas are often many hundreds of meters apart. It would be impractical to add the signals and use a Dicke circuit, because of attenuation in the feed cables. If amplifiers were inserted at each antenna, their gain fluctuations would not be eliminated by the Dicke radiometer. Thus the formula as given is applicable in this case.

Graham's suggestion for improving the Dicke circuit seems incorrect. To see this, consider a single sine wave input to the radiometer, and express the square wave input to the modulator in a Fourier series. The series contains only terms with frequencies q, $3q$, $5q$, etc. But the output of the square-law detector contains no terms of these frequencies, so there can be no dc at the output of the multiplier. The detector does not distinguish between a phase modulated and an unmodulated signal. The presence of many input sine waves does not modify this result.

D. H. Ring[7] has pointed out an error in the calculation of $R_3(\tau)$ in the analysis of the Dicke radiometer. The second term should have an additional factor $\frac{1}{2}$. The corrected formula for σ_{sd}^2 for the Dicke circuit with sine wave modulation is obtained by deleting the factor $\sqrt{2}$. Ring also found an error in the reasoning used to analyze the effect of a square wave modulator. The signal term in the output of the square law detector is the product of the amplitude of the fundamental component and the amplitude of the constant term in the modulating waveform. Changing from sinusoidal to square wave modulation, therefore, increases the output signal by $4/\pi$ rather than by $16/\pi^2$. The corrected sensitivity formulas for the Dicke radiometer are.

$\sigma_{1d}^2=4\sigma_n^2\sqrt{\gamma/\alpha}$ sine wave modulation and sine wave input to the multiplier.

$\sigma_{1d}^2=\pi\sigma_n^2\sqrt{\gamma/\alpha}$ square wave modulation and sine wave input to the multiplier.

Use of square wave input to both the modulator and multiplier gives approximately the same sensitivity as with both sine wave inputs, provided that the bandpass filter passes the harmonics of q.

The formula for the two-receiver radiometer in terms of total input power is

$$\sigma_{1d}^2 = 2\sigma_n^2\sqrt{\frac{\gamma}{\alpha}}.$$

Fortunately, the errors are numerically quite small, and the conclusions of the original paper are unaffected.

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[6] Received by the IRE, October 16, 1956.
[7] D. H. Ring, Bell Telephone Labs., Holmdel, N. J., private communication.

Miller Integrator*

A useful property of the Miller Integrator not emphasized in the literature is its ability to generate a linear sweep whose peak voltage considerably exceeds the dc supply voltage.

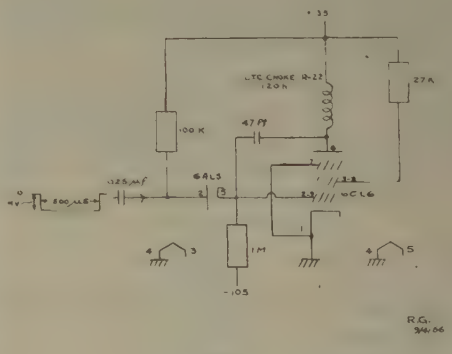


Fig. 1

Fig. 1 shows such a circuit which develops a linear sawtooth of approximately 1000 volts peak with a dc plate supply of 35 volts.

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* Received by the IRE, September 11, 1956.

Realizability of a Prescribed Frequency Variation of Dielectric Constant*

A modification of the Kronig-Kramers relations is used to derive the value of the minimum attainable loss in a dielectric having an inverse square dependence on frequency of the real part of the dielectric constant, over a given band.

In designing radio-frequency devices involving dielectric materials, it would often be desirable to find dielectrics having such a frequency variation of the dielectric properties as to extend the useful bandwidth of the corresponding device over one employing a dielectric having dielectric constant independent of frequency.

A case frequently encountered, for example that of a quarter-wavelength matched load, or half-wavelength dielectric window, is where the dielectric must have a linear dimension equal to a constant fraction of the wavelength measured in the dielectric medium. If the application involves plane waves, for which the material wavelength varies inversely as the frequency, f, and the square root of the dielectric constant, it might be proposed to use a material whose dielectric constant varies as $1/f^2$, thus maintaining a constant material wavelength.

Unhappily it is found that real dielectric materials having rapid variations of dielectric constant with frequency are also quite lossy, and as a result may not be applicable to devices requiring low loss. This coupling of high loss tangent with rapid frequency variation of dielectric constant is, of course, not accidental.

The well-known Kronig-Kramers relations[1] between real and imaginary components of dielectric constant describe the connection analytically. We should like to demonstrate how the use of these relations leads to a quantitative evaluation of the minimum loss tangent consistent with the inverse square variation of the real part of the dielectric constant over any specified frequency band.[2]

In the usual form of the Kronig-Kramers equations the value of $\epsilon_1(f)$, the real part of the dielectric constant $\epsilon(f)=\epsilon_1(f)-j\epsilon_2(f)$ at frequency f, is given in terms of an integral of $\epsilon_2(f)$ over the frequency range, zero to infinity.

Similarly $\epsilon_2(f)$ is given in terms of an integral of $\epsilon_1(f)$ over the same infinite frequency range.

A more convenient form of the equations for the present analysis, where $\epsilon_1(f)$ is specified over a finite band, arises from modification of the corresponding equations in network analysis.[3] Namely

$$= -\epsilon_1(f)+\epsilon_\infty, \qquad f<f_a$$

$$\frac{2}{\pi}\left|1-\frac{f^2}{f_a^2}\right|^{1/2}\left|1-\frac{f^2}{f_b^2}\right|^{1/2}(R+S+T)=\epsilon_2(f), \qquad f_a<f<f_b$$

$$=\epsilon_1(f)-\epsilon_\infty, \qquad f>f_b,$$

where

$$R=\int_0^{f_a}\frac{f_af_bx\epsilon_2(x)dx}{\sqrt{(f_a^2-x^2)(f_b^2-x^2)(f^2-x^2)}}$$

$$S=\int_{f_a}^{f_b}\frac{f_af_bx[\epsilon_1(x)-\epsilon_\infty]dx}{\sqrt{(x^2-f_a^2)(f_b^2-x^2)(f^2-x^2)}} \qquad (1)$$

$$T=\int_{f_b}^{\infty}\frac{f_af_bx\epsilon_2(x)dx}{\sqrt{(x^2-f_a^2)(x^2-f_b^2)(x^2-f^2)}}$$

and ϵ_∞ is the limiting value of ϵ_1, at infinite frequency.

In the present application our interest is in the value of $\epsilon_2(f)$ within the range $f_a<f<f_b$. This value depends upon the three integrals R, S, T. The integrals R and T depend upon the value of $\epsilon_2(f)$ outside the range of interest. For present purposes we need only note that since ϵ_2 can never be negative, the integrals R and T must similarly be nonnegative for $f_a<f<f_b$. The integral S may be evaluated upon the assumption $\epsilon_1(f)=\epsilon_1(f_a)(f_a^2/f^2)$ for $f_a<f<f_b$, taking note of the fact that the principal value of the integral must be taken about the singularity. The result is, $S=(\pi/2)\epsilon_1(f)$. Therefore

$$\frac{\epsilon_2(f)}{\epsilon_1(f)}\geq\left(\frac{f^2}{f_a^2}-1\right)^{1/2}\left(1-\frac{f^2}{f_b^2}\right)^{1/2} \qquad (2)$$

for $f_a<f<f_b$, provided $\epsilon_1(f)\propto 1/f^2$ for this same interval. The equality sign holds only if $\epsilon_2(f)$ is zero for all $f>f_b$ and $f<f_a$. In this case

$$=\frac{f_a}{f_bf^2}(f_af_b-\sqrt{(f_a^2-f^2)(f_b^2-f^2)}), \qquad f<f_a$$

$$\frac{\epsilon_1(f)}{\epsilon_1(f_a)}=\frac{f_a^2}{f^2}, \qquad f_a<f<f_b$$

$$=\frac{f_a}{f_bf^2}(f_af_b+\sqrt{(f^2-f_a^2)(f^2-f_b^2)}), \qquad f>f_b.$$

The result is then that where one is dealing with a large bandwidth the loss tangent becomes large over most of that band. Over narrow bands the loss tangent is not required to become larger than about $(\Delta f/f)$ where $\Delta f/f$ is the fractional bandwidth.

It is hoped that the above illustration of the application of the Kronig-Kramers relations in obtaining quantitative limits on the dielectric properties of a material may suggest other applications where similar methods can fix fundamental limitations on dielectric behavior and at times may forestall a useless search for a material with unusual properties.

I appreciate help from Dr. J. C. Bell with the integrations, and I wish to thank Dr. D. T. Williams for cooperation with this work.

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Columbus 1, Ohio

On Angular Velocity*

Buss has recently contributed important viewpoints on the names of ω and $\mathbf{s}$, and also discussed names for their units.[1] Since Buss states that the purpose of his article is to invite discussion and suggestions for possible words, this writer accepts the invitation as follows.

The English language uses the unwieldy two-word designation "angular velocity," or a similar two-word designation, such as "radian frequency," while other languages are fortunate to have one-word designations, such as the German *Kreisfrequenz* and the Swedish *vinkelfrekvens*. Translating these into English, we seem, nevertheless, to end up with two words. (The two quoted terms may be criticized for employing "frequency," while the English "angular velocity" is free from this misnomer.) From the point of view of the international mathematician, the problem brought up by Buss is to some extent a language problem.

Buss has correctly observed that the *complex frequency*, to the extent accepted, is $\mathbf{s}/2\pi$ and not $\mathbf{s}$ (*i.e.*, he correctly refers to $\mathbf{s}$ as complex angular velocity), which is indeed encouraging in view of the widespread corruption of the term "complex frequency" in today's technical and scientific literature. The suggested term "freqrad" (or, why not, "radfreq") is a step in the right direction, but seems not fully convincing. Buss has coined the term "complex freqrad" (unless this writer misunderstands him), which in case of $\mathbf{s}=\sigma+j\omega$ would mean that in the extreme, for $\omega=0$, "freqrad" refers to a quantity, which has nothing to do with "radian." The quantity σ pertains to damping, and signifying the greatest advantage of the Laplace integral over the Fourier integral, it is to its nature of the inverse-time variety, just like ω (since radian is dimensionless), and in 1946 the writer introduced σ as *log frequency*, when ω was (improperly) called radian frequency, and as *log velocity*, when ω more appropriately was referred to as angular velocity.[2] Continuing along this line of thought, the writer now suggests as an alternative to "freqrad" the term *spinvel* for angular velocity ω, derived from "spinning velocity" (in angular measure). *The adoption of this suggestion means that the misleading term "frequency" is fully removed from the angular velocity concept*, and we would now say

* Received by the IRE, October 29, 1956.

[1] J. H. Van Vleck, "Propagation of Short Radio Waves," M.I.T. Rad. Lab. Ser., No 13, D. E. Kerr Ed., McGraw-Hill Book Co., Inc., New York, N. Y., pp. 641–643; 1951. H. Fröhlich, "Theory of Dielectrics," Oxford University Press, London, Eng., Sec. 2; 1949.

[2] That the inverse-square variation of the dielectric constant is unattainable over any wide frequency range in a low-loss dielectric may also be deduced from the fact that a condenser filled with such a dielectric would possess a negative reactance having magnitude increasing linearly with frequency.

[3] H. W. Bode, "Network Analysis and Feedback Amplifier Design," D. Van Nostrand Co., Inc., New York, N. Y., ch. 14; 1945.

* Received by the IRE, October 23, 1956.

[1] R. R. Buss, "On the use of a special word for the quantity 'angular velocity,'" Proc. IRE, vol; 44, p. 1054: August, 1956.

[2] H. Stockman, "The $j\omega$- or Symbolic Method," SER Co., Waltham, Mass., pp. i-ll; 1056.

$$s = \sigma + j\omega$$

$$\text{complex spinvel} = \text{logvel} + j(\text{spinvel}),$$

where "log velocity" is contracted to "logvel." The unit for "logvel" is nepers per second, the unit for "spinvel" is radians per second, and the unit for "complex spinvel" is the ideal unit "nerad," introduced by Buss.

In doing away with the standards we live by, is it not just as important that we consider "the thing" that spins around, with reference to ω in ac theory; voltages, currents, and charges. More plainly, let us *once and for all* do away with the spinning *vector* in ac theory, in favor of the *phasor* and its ill-treated step-child, the *sinor*. How can sound-thinking engineers continue year after year to call scalar quantities vectors? What about the hoax that $j\omega$ is an algebraic quantity (which would mean that it is the sum of j pieces, each one being ω), or the still bigger hoax that by rigorous mathematical thinking we obtain -1 because we can take the square (meaning j^2) of a square root, when in reality there is no square, since j^2 does not mean "j squared" but merely indicates that the operation has been performed twice! As a world authority in this field, Emeritus Prof. J. Hollingworth of the University of Manchester, England, puts it: "It would have saved a lot of trouble if it had been written j_2" ("it" standing for j^2).[3] Adding more "what abouts," how come that "instantaneous complex quantities" still do not rate symbols of their own, such as I_t for $Ie^{j\omega t} = Ie^{j(\omega t+\alpha)}$? Returning to $s=\sigma+j\omega$, ω is called "real frequency," and still worse, σ is sometimes called "imaginary frequency." In the first place, neither one is a frequency, and σ is just as real as ω, so "real frequency" fails to provide the proper distinction, and if anything should be associated with "real," it seems that it should be the first quantity σ in $s=\sigma+j\omega$, not the second quantity ω. The worst misnomer of them all, in this writer's opinion, is, however, *imaginary*, used by Buss and most everybody else. This unfortunate term, introduced some three hundred years ago by René Descartes (1596–1650), seems slated to becloud our minds for all future, giving young students the idea that they are playing around with fictitious things from an "imaginary world." This can be at least partly avoided in straight-forward presentation of $s=\sigma+j\omega$ if we say that σ is the real (or reference, or prime-direction) part, that $j\omega$ is the j term, and that ω is the j part, or, if we so wish, the quadrature part.[4] This terminology, in which "imaginary axis" is replaced by "j axis," also eliminates the controversy of $\omega = \text{Im}(s)$, the real ω being the imaginary part of something, and substitutes the well-known writing $\omega = Q(s)$, where Q is inspired by "quadrature."

Many difficulties, such as the ones mentioned above, are still thrown in the path of the young electrical engineering student, and this fact is mentioned here as a serious suggestion that if we cleaned up the fundamentals, perhaps the pieces would all fit together when we would come to higher learning, so that this discussion, ably started by Buss, would not be necessary.

HARRY STOCKMAN
Neutronics Research Co.
Waltham, Mass.

[3] J. Hollingworth, "The symbolic method," *Bull. Elec. Engr. Education, England*, no. 10, pp. 22–23; June, 1953.
[4] H. Stockman, "On reciprocal inductance," PROC. IRE, vol. 43, p. 341; March, 1955.

Information Rate of a Human Channel*

The rate at which a human being can respond to and reproduce information is important in communication and in properly relating machines to human beings. Previous studies[1,2] have indicated that reading aloud randomized lists of words leads to a higher information rate than, for instance, typing, playing randomized sequences of notes on a piano, or tracking (pointing). Licklider,[1] using words chosen randomly from a dictionary, found a higher information rate for tracking and reading simultaneously[3] than for reading alone.

We obtain our highest rates, 42–43 bits/second, by using a "code" consisting either of the 2500 most common monosyllables[4] (11.3 bits/word), or prose scrambled or randomized over long stretches (11.82 bits/word[5]). These rates are as high as those which Licklider obtained for reading and tracking simultaneously. With our code, reading and tracking simultaneously gives a lower information rate.

We find that reading rates vary among individuals and groups, being low (~2 words/second) among porters and high (~3 words/second) among engineers. For a given individual, reading rate varies with familiarity (among which thousandth in order of frequency of usage the words are chosen) and with number of syllables, as shown in Fig. 1. Nonsense words are at first read slowly, but with increased familiarity the rate approaches that for meaningful words.

Experiments indicate that the limitation on reading rate is a very fundamental one, mental rather than muscular (limitation on rate of utterance), as illustrated by the fact that a phrase can be repeated or prose read faster than randomized lists can be read (Fig. 2). Neither does the limitation seem to be one associated with our mode of writing, for two bilingual Chinese readers read randomized lists of common Chinese characters at almost the same rate at which they read randomized lists of the corresponding English words.

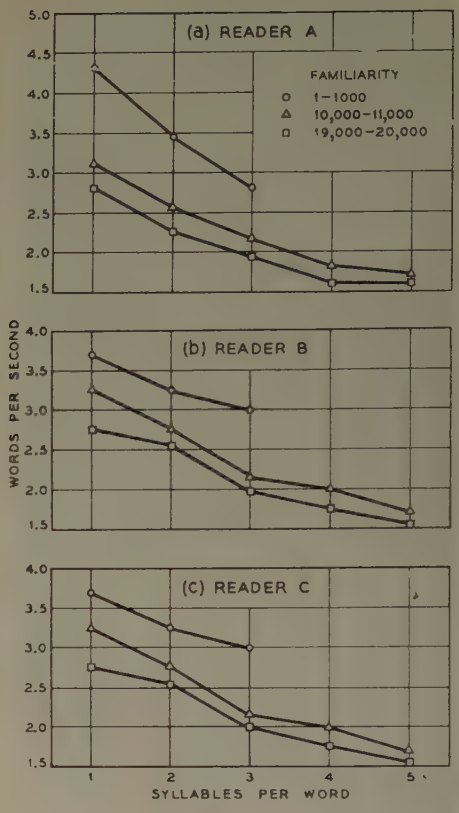


Fig. 1

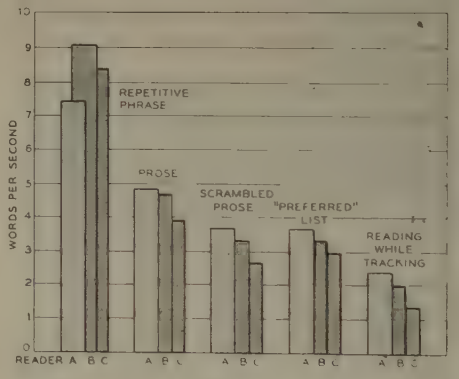


Fig. 2

In all, we have found a lower bound of some 43 bits/second to the rate at which information can be transmitted through a human channel. This rate can be reached by reading aloud randomized lists of the 2500 most familiar monosyllables. Longer or shorter lists (more or less complex tasks) give lower rates. The limitation on the rate appears to be mental rather than muscular. No higher rate has been achieved through multiple tasks. Because the limitation appears to be a mental one, it may imply that information rates of this order could provide satisfactory sensory inputs in sound or picture transmission. We plan to publish our results more comprehensively in an early issue of the *Bell System Technical Journal*.

J. R. PIERCE AND J. E. KARLIN
Bell Telephone Labs., Inc.
Murray Hill, N. J.

* Received by the IRE, October 15, 1956.
[1] J. C. R. Licklider, K. N. Stevens, and J. R. M. Hayes, "Studies in Speech, Hearing and Communication," Mass. Inst. Tech., Acoustics Lab. Tech. Rep.; September 30, 1954.
[2] H. Quastler, *et al.*, "Human Performance in Information Transmission," University of Illinois, Control Systems Lab. Rep. no. R-62; March, 1955.
[3] In Licklider's case, "tracking" means touching the interior of a box drawn beside the word; in our case it means putting a dot close to a short vertical line to the right of a word.
[4] E. L. Thorndike, "A Teacher's Word Book of the Twenty Thousand Words Found Most Frequently . . . ," Columbia University Teachers College; 1932.
[5] C. E. Shannon, "Prediction and entropy of printed English," *Bell Sys. Tech. J.*, vol. 30, pp. 50–64; January, 1951.

Contributors

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R. D. HATCHER

Mr. Hatcher taught physics and electronics at the Naval Academy from 1944 to 1948. Since 1948 he has been a member of the staff of the National Bureau of Standards and the Diamond Ordnance Fuze Laboratories. He is Chief of the Microwave Development Section at DOFL.

❖

Robert A. Pucel (S'48–A'52–S'54–M'56) was born on December 27, 1926, in Ely, Minn. After serving in the U. S. Navy from 1945 to 1946, he entered the Massachusetts Institute of Technology and received the B.S. and M.S. degrees in electrical engineering in 1951. From 1948 to 1951 he was enrolled in a cooperative plan and worked for the General Electric Company.



R. A. PUCEL

Following his graduation in 1951, Dr. Pucel joined the Research Division of the Raytheon Manufacturing Company, Waltham, Mass., where he was a member of the Microwave Noise Study Group. In 1952, he returned to M.I.T. as a doctoral candidate, and was also a staff member of the Research Laboratory of Electronics. He received the degree of Doctor of Science in electrical engineering in 1955 from M.I.T.

In 1955, he rejoined the Research Division at Raytheon as a staff member of the Theoretical Physics Group, where he is principally engaged in the study and application of new solid-state device concepts.

Dr. Pucel is a member of Sigma Xi.

❖

Jan A. Rajchman (SM'46–F'53) was born in London, England, on August 10, 1911. He received his diploma in electrical engineering in 1934 and the degree of Doctor in technical sciences in 1938 from the Swiss Institute of Technology, Zurich, Switzerland. He started in the Summer of 1935 as a student engineer at RCA Manufacturing Co. in Camden. In 1936 he joined the staff of RCA Manufacturing Co. as a research engineer and in 1942 he was transferred to the RCA Laboratories in Princeton where he is a member of the research staff.



J. A. RAJCHMAN

At first Dr. Rajchman worked in electron optics. He is chiefly responsible for the development of the electron multiplier tube. During the war he was among the first to apply electronics to computers. Later he worked on the betatron for which he became a co-recipient of the 1947 Levy Medal of the Franklin Institute. After the war he resumed work on computing devices. He developed the selective electrostatic storage tube. Turning to the new field of magnetics he developed the magnetic core memory, magnetic switching circuits, and more recently the transfluxor. He is presently active in the field of magnetics and other solid state devices.

Dr. Rajchman is a member of the American Physical Society, the Council of the Association for Computing Machinery, and Sigma Xi. He has been granted more than 50 U. S. patents.

❖

Frank Reggia (A'55) was born in Northumberland, Pennsylvania, on October 30, 1921. He attended George Washington University, and the University of Maryland, and is a graduate of Radio Matériel School at the Naval Research Laboratory in Washington, D. C. While a member of the Armed Forces, he served as an electronic specialist in both the United States and in the Pacific Theater. Following separation in 1945, he joined the staff of the Microwave Standards Section of the National Bureau of Standards, where he was engaged in research and development in a microwave standards program.

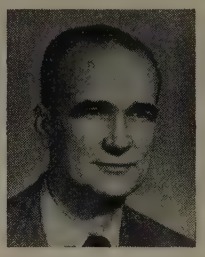


F. REGGIA

Mr Reggia joined the technical staff of the Diamond Ordnance Fuze Laboratories, Department of the Army, Washington, D. C., in 1954. Since then he has been engaged in measurement techniques and applications of ferrites at microwave frequencies. He is a member of the Washington Society of Engineers. He received the Washington Society of Engineers' award for 1953.

❖

William Shockley (SM'51–F'55), one of three recipients of the 1956 Nobel Prize in Physics for his work on semiconductors and discovery of the transistor effect, was born in London, England, on February 13, 1910. He received the B.S. degree in 1932 from California Institute of Technology. Continuing his studies at Massachusetts Institute of Technology on a teaching fellowship, he received the Ph.D. degree in physics in 1936.



W. SHOCKLEY

In September of that year he joined Bell Telephone Laboratories, where his work included vacuum-tube and electron-multiplier design, radar development, solid-state physics, magnetism, and semiconductors.

In 1942, Dr. Shockley was assigned to Columbia University Division of War Research as Director of Research for the Anti-submarine Warfare Operations Research Group. In 1944 he became a consultant to the Office of the Secretary of War.

Returning to Bell Telephone Laboratories in 1945, he became director of transistor physics, and in collaboration with W. H. Brattain and John Bardeen, worked on the development of the transistor.

At present, Dr. Shockley is director of the Shockley Laboratory of Beckman Instruments, Inc., Mountain View, Calif.

He was awarded the IRE Medal for Merit in 1946 and the Morris Liebmann Award in 1952, and in 1951 was elected to the National Academy of Sciences. In June, 1956, Rutgers University awarded him the honorary degree of Doctor of Science. He is a member of the American Physical Society, Tau Beta Pi, and Sigma Xi.

❖

Edward G. Spencer was born on July 21, 1920, at Lynchburg, Va. He received the B.S.E. degree in physics from George Washington University and the M.A. degree in physics from Boston University. He did further graduate work at Massachusetts Institute of Technology and at the University of Maryland. From 1943 to 1946 he was engaged in microwave radar research at the Naval Research Laboratory.



E. G. SPENCER

From 1946 to 1949 Mr. Spencer was associated with the Cambridge Air Force Research Laboratory, and from 1949 to 1953 with the Naval Research Laboratory. During this time he worked in microwave spec-

troscopy of gases and paramagnetic and nuclear magnetic resonance of solids. In 1953, he joined the National Bureau of Standards, Ordnance Electronics Division, which is now the Diamond Ordnance Fuze Laboratories. He is at present engaged in microwave physics research.

Mr. Spencer is a member of the American Physical Society.

❖

Hermann Statz was born in Germany on January 9, 1928. He received the Diploma in Physics in 1949, and the Doktor der Naturwissenschaften degree in 1951, from the Technische Hochschule, Stuttgart. During 1949 to 1951, he was a research associate at the Max Planck Institut für Metallforschung Stuttgart. From 1951 to 1952, he held a research stipend from Deutsche Forschungsgemeinschaft; his work was concerned with problems in theoretical solid state physics. In 1952 he joined the staff of the Solid State and Molecular Theory Group at the Massachusetts Institute of Technology, where he worked on the theory of ferromagnetism. Since 1953 he has been with the Research Division of Raytheon Manufacturing Co., Waltham, Mass., doing research in solid state physics and related fields.



H. Statz

Dr. Statz is a member of the American Physical Society.

Arthur P. Stern (A'51–SM'55) was born on July 20, 1925 in Budapest, Hungary. He studied at the Universities of Budapest and Lausanne and at the Swiss Federal Institute of Technology in Zurich, where he acquired the Master's degree in electrical engineering in 1948.



A. P. Stern

From 1948 to 1951, Mr. Stern did research and development work in the field of gaseous discharges in Switzerland. In 1950, he became instructor for illumination engineering and photometry at the Swiss Federal Institute of Technology.

Mr. Stern came to the United States in 1951 and joined the staff of the General Electric Company's Electronics Laboratory in Syracuse, N. Y. He worked first in the field of color television systems and shifted his activities later to problems of solid state and, in particular, transistor circuitry. At the present time, Mr. Stern heads the Advanced Circuits development section of the Electronics Laboratory.

Mr. Stern is a member of the Scientific Research Society of America, and an associate member of AIEE.

❖

John E. Tompkins was born in Waterloo, Iowa, in 1922. He received the Bachelor's and Master's degrees in physics from George Washington University. During the war he worked in mass spectrometry at Oak Ridge.

Since 1949 Mr. Tompkins has been employed as a microwave physicist at the Bureau of Standards and the Diamond Ordnance Fuze Laboratories.



J. E. Tompkins

Mr. Tompkins is a member of Sigma Pi Sigma, The American Physical Society, The American Association of Physics Teachers, and an associate member of Sigma Xi.

❖

James P. Wittke was born in Westfield, N. J. on April 2, 1928. He received the M.E. degree from Stevens Institute of Technology in 1949 and the M.A. and Ph.D. degrees in physics from Princeton University in 1952 and 1955, respectively.



J. P. Wittke

After a year as instructor at Princeton University, Dr. Wittke joined the technical staff at RCA Laboratories. Since 1955, he has been engaged in an experimental and theoretical study of molecular amplification.

He is a member of the American Physical Society, Sigma Xi, and Tau Beta Pi.

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Convention Highlights

Technical Program

A schedule of 55 technical sessions appears on the next page, followed by abstracts of the more than 280 papers to be presented.

Radio Engineering Show

This year's exhibition will be held in a new convenient location, the New York Coliseum at 59th St. and 8th Ave. A list of the 840 exhibitors and their products appears in "Whom and What to See at the Radio Engineering Show" in the advertising section of this issue.

Annual Meeting

Time: 10:30 A.M., Monday, March 18.
Place: Grand Ballroom, Waldorf-Astoria Hotel.
Speaker: Donald G. Fink, Director of Research of Philco Corporation and Editor of IRE, "Electronics and the IRE-1967."

The special features of this opening meeting of the convention will be of particular interest to all IRE members.

Annual IRE Banquet

Time: 6:45 P.M., Wednesday, March 21.
Place: Grand Ballroom Waldorf-Astoria Hotel.
Guest Speaker: Dr. John A. Hannah, President, Michigan State University.
Presentation of IRE Awards: John T. Henderson, IRE President.
Spokesman for IRE Fellows: Major General James D. O'Connell, U.S. Army Signal Corps.
Toastmaster: Rear Admiral Charles F. Horne, Convair.

Cocktail Party

Time: 5:30–7:30 P.M., Monday, March 18.
Place: Grand Ballroom, Waldorf-Astoria Hotel.

Women's Program

An entertaining program of tours and shows has been arranged for the wives of members. Women's headquarters will be located in the Regency Suite on the fourth floor of the Waldorf.

SCHEDULE OF TECHNICAL SESSIONS

* Sessions Terminate at 12:00 Noon.

	WALDORF-ASTORIA					NEW YORK COLISEUM		
	Starlight Roof	Astor Gallery	Jade Room	Sert Room	Grand Ballroom	Morse Hall	Marconi Hall	Faraday Hall
Monday March 18 2:30 P.M.–5:00 P.M.	*Session 1* NONLINEAR CONTROL SYSTEMS	*Session 2* VEHICULAR COMMUNICATIONS	*Session 3* PROPAGATION	*Session 4* ULTRASONICS ENGINEERING I—An Educational Session	*Session 5* AERONAUTICAL ELECTRONICS	*Session 6* MULTIPLEX COMMUNICATIONS SYSTEMS	*Session 7* INFORMATION THEORY—Coding and Detection	*Session 8* SOLID-STATE DEVICES
Tuesday March 19 10:00 A.M.–12:30 P.M.	*Session 9* AUTOMATIC CONTROL—General	*Session 10* NAVIGATION	*Session 11* NEW BROADCAST DEVELOPMENTS	*Session 12* ULTRASONICS ENGINEERING II—Technical Session	*Session 13** ENGINEERING MANAGEMENT VIEWPOINTS	*Session 14* ANTENNAS I—General	*Session 15* INFORMATION THEORY—Review and Recent Advances	*Session 16* MICROWAVE TUBES
Tuesday March 19 2:30 P.M.–5:00 P.M.	*Session 17* GENERAL COMMUNICATIONS SYSTEMS	*Session 18* MEDICAL ELECTRONICS	*Session 19* NEW OPERATIONAL TECHNIQUES CONCERNING VIDEO TEST SIGNALS (A Panel Discussion)	*Session 20* HIGH FIDELITY AND HOME MEASUREMENTS		*Session 21* ANTENNAS II—Broadband Antennas	*Session 22* INFORMATION THEORY—Applications	*Session 23 (Joint)* TELEVISUAL SYSTEMS DEVICES
Tuesday March 19 8:00 P.M.–10:30 P.M.	*Session 24 (Joint)* APPLICATIONS OF ELECTRONICS TO AIR TRAFFIC CONTROL							*Session 25 (Joint)* MICROMINIATURIZATION—The Ultimate Technique
Wednesday March 20 10:00 A.M.–12:30 P.M.	*Session 26* ELECTRONIC COMPUTERS I—Digital Computers	*Session 27* MAGNETIC RECORDING	*Session 28* NUCLEAR INSTRUMENTATION	*Session 29* CIRCUIT THEORY I—Symposium: Modern Methods in Network Theory	*Session 30** ENGINEERING MANAGEMENT TECHNIQUES	*Session 31* TRANSISTOR APPLICATIONS	*Session 32 (Joint)* MICROWAVE ANTENNAS	*Session 33* ELECTRON TUBES—General
Wednesday March 20 2:30 P.M.–5:00 P.M.	*Session 34* SYMPOSIUM: LONG RANGE TELEMETRY AND REMOTE CONTROL	*Session 35* SPEECH ANALYSIS AND AUDIO AMPLIFIERS	*Session 36* TRANSISTORIZING NUCLEAR INSTRUMENTATION	*Session 37 (Joint)* SYMPOSIUM: APPLICATIONS OF COMPUTERS IN BIOLOGY AND MEDICINE		*Session 38* COLOR TELEVISION RECEIVERS	*Session 39* MICROWAVES I—Components	*Session 40* PRODUCTION TECHNIQUES
Thursday March 21 10:00 A.M.–12:30 P.M.	*Session 41* ELECTRONIC COMPUTERS II—Symposium: Computers in Simulation, Data Reduction, and Control	*Session 42* CIRCUIT THEORY II—Transistor and Amplifier Circuit Design	*Session 43* COMPONENT PARTS I	*Session 44* INDUSTRIAL ELECTRONICS	*Session 45** RELIABILITY PROBLEMS	*Session 46* SYMPOSIUM: DIGITAL TECHNIQUES FOR PROBLEMS IN TELEMETERING AND REMOTE CONTROL	*Session 47* MILLIMICROSECOND INSTRUMENTATION—Special Topics	*Session 48* MICROWAVES II—Switches
Thursday March 21 2:30 P.M.–5:00 P.M.	*Session 49* ELECTRONIC COMPUTERS III—Mainly Analog	*Session 50* CIRCUIT THEORY III—Network Design Techniques	*Session 51* COMPONENT PARTS II	*Session 52* ANALYSIS AND TECHNIQUES FOR IMPROVED RELIABILITY		*Session 53* SYMPOSIUM: LOW LEVEL MULTIPLEXING FOR TELEMETERING AND REMOTE CONTROL	*Session 54* INSTRUMENTATION II	*Session 55* MICROWAVES III—General

ABSTRACTS OF TECHNICAL PAPERS

SESSION 1*

MON. 2:30–5:00 P.M.

WALDORF-ASTORIA STARLIGHT ROOF

Nonlinear Control Systems

Chairman: M. R. Aaron, *Bell Telephone Labs., Murray Hill, N. J.*

1.1. Nonlinear Compensating Networks for Feedback Systems

E. Mishkin and J. G. Truxal, *Polytechnic Institute of Brooklyn, Brooklyn, N. Y.*

A class of nonlinear networks for the compensation of linear and nonlinear feedback systems is described. The nonlinear networks are restricted to tandem, parallel, or feedback networks involving diode realization of the frequency-independent, nonlinear portion of the network and active, RC realization of the linear, frequency-dependent portion. The entire compensating network is inserted in a low-power-level, subsidiary feedback path.

Analog-computer and actual-system studies are described to indicate the results in two systems, one involving backlash and the other the combination of saturation and dead zone separated by a linear, integrating system.

1.2. Direct Synthesis through Block Diagram Substitutions

O. J. M. Smith, *Elec. Eng. Div., University of California, Berkeley, Calif.*

A direct synthesis procedure is presented which starts with a block diagram representation of four statements. These statements are: the problem, the restrictions, the criteria for design, and the optimum possible mode of operation. Each of these is presented as a block diagram, and the four are combined for a resultant statement of the problem. By the application of certain types of block diagram substitutions, the resultant system design can be obtained directly. Examples are shown for the control of dead time and nonminimum phase zeros, lightly-damped oscillatory systems, nonlinear control of saturating systems, and statistical synthesis.

1.3. A Nonlinear Control System for Wide-Range Input Signals

J. Tou and Y. H. Ku, *Moore School of Elec. Eng., University of Pennsylvania, Philadelphia, Pa.*

This paper gives a nonlinear control system for improving servosystem performance when the input signal varies over a wide dynamic range, causing sensitive controllers and error-detectors to undergo saturation and lose accuracy. In parallel with the controller of a servosystem, a nonlinear device is connected which is inactive when the signal is below a certain preset range. When the signal gets beyond this range, the sensitive control becomes saturated and the nonlinear device forms a by-pass for sending adequate information to the controlled system. Thus a combination of precision and coarse controls is incorporated in the system. Several possible cases are investigated. Analysis and design of such nonlinear control systems are described in the paper.

1.4. Switching Discontinuities in Phase Space

J. C. Hung and S. S. L. Chang, *Dept. of Elec. Eng., New York University, New York, N. Y.*

In an "optimum" nonlinear servosystem, which may either be of the contactor type or of the saturated type, the error derivatives are not continuous at the moment of switching if the transfer function of the controlled system has a polynomial in s as its numerator.

The above effect, which has hitherto been neglected in the literature, forms the basis for a general, modified phase-space switching criteria for nonlinear servos of this type. The theory is applied to the depth control problem of a submarine to determine its theoretical optimum switching boundaries.

1.5. Nonlinear Techniques Applied to the Analysis of Pilot-Induced Oscillations

I. Van Horn, *Convair Div., General Dynamics Corp., San Diego, Calif.*

The advent of high-speed aircraft has brought stability control problems which stem from the fact that the human pilot is a part of the closed loop causing oscillations. Two factors combine to make analysis of the system difficult. They are the unpredictability of the pilot transfer function and the nonlinearity of the pilot controls.

This paper uses describing-function techniques together with a simplified representation of the pilot transfer function to analyze pilot-induced oscillations. Comparisons are made with flight test results to verify the conclusions reached.

* Sponsored by the Professional Group on Automatic Control. To be published in Part 4 of the 1957 IRE Convention Record.

SESSION 2*

MON. 2:30–5:00 P.M.

WALDORF-ASTORIA ASTOR GALLERY

Vehicular Communications

Chairman: C. M. Heiden, *General Electric Co., Syracuse, N. Y.*

2.1. How Far Can We Go in Narrowing Channels in the Land Mobile Radio Services?

C. B. Plummer, *Federal Communications Commission, Washington, D. C.*

The ratio of assigned channel bandwidths to intelligence bandwidths has been gradually reduced from about 60 to 1 to 10 to 1 in the last 10 years. Will equipment manufacturers 10 years hence approach a ratio of 1 to 1?

2.2. Practical Modern Network Theory Design Data for Crystal Filters

M. Dishal, *Federal Telecommunication Labs., Nutley, N. J.*

In many radio systems (for communication, navigation, counter-measures, etc.) it is often desired that the system band-pass response be supplied by a single lumped filter having these two characteristics: 1) A high rate of cutoff in db per octave outside the pass band, and 2) a high "fractional midfrequency," *i.e.*, a high (fo/BW_{3db}).

For midfrequencies up to vhf it will be shown that when the required product of the above two characteristics is greater than approximately 800, it is impractical to satisfy the band-pass filter specification with "economical" LC resonators because of their limited unloaded Q.

Because quartz-crystal resonators have appreciably higher unloaded Q's, it is logical to consider their use when faced with the above specifications.

However, most of the information available on the design of crystal filters is based on the design procedures of image-parameter-theory. Because the generator and load impedances physically available can never satisfy the "characteristic impedance" requirement of this theory, this design information is only approximately "correct." In this present paper the design procedures of modern network theory are applied to some of the most useful crystal filter configurations, and the more accurate design data which results is presented.

2.3. Recent Developments in Mobile Radio in Britain

J. R. Brinkley, *Pye Telecommunications, Ltd., Cambridge, Eng.*

The paper outlines briefly the development of vhf mobile radio in Great Britain and describes why AM is dominantly used as opposed to fm.

The first ten years of development have been based on two frequency bands 71.5—88 and 156—184, and 50-kc channeling has been used in the lower and 100 kc in the higher bands.

A second phase of development is being entered. This has been precipitated by the loss of channels to commercial tv and to the pressure for more mobile channels. This has led in turn to the need for closer channel spacing and more stringent specifications. Fifty-kc channeling becomes mandatory in 1957 and already apparatus capable of 25-kc channel spacing is in operation in both bands.

The paper concludes with a reference to the standardization of fm for international marine purposes and considers the future of AM and fm systems in relation to even closer channel spacings.

* Sponsored by the Professional Group on Vehicular Communications. To be published in Part 8 of the 1957 IRE Convention Record.

2.4. A Manually-Operated Demand Repeater for the 450–470-MC Band

S. F. Meyer, *Allen B. DuMont Labs., Inc., East Paterson, N. J.*

Channel assignments for land-mobile services in the 450 to 470-mc frequency band offer many advantages to various user groups. One disadvantage, however, is the relatively poor mobile-to-mobile coverage compared to the lower frequency bands. This paper describes a relatively inexpensive modification to existing base station designs thereby permitting it to operate as an "In-The-Band" repeater. The mode of operation (dispatch vs repeater) is selectable by the system dispatcher. The overall result is a land-mobile system in the uhf band with unusual flexibility available on an extremely economical basis.

2.5. Sinad Interference Evaluation by Vosim

N. H. Shepherd, *General Electric Co., Syracuse, N. Y.*

A new method of adjacent channel interference evaluation which closely simulates actual operating conditions will be described. Several methods have been used in the past to evaluate adjacent channel interference, such as tone and noise modulation on the interfering signal. Each of those methods of modulation have failed to reproduce levels of interference comparable to typical voice modulation. This paper will show the results of interference levels produced by typical voice modulation compared to Vosim modulation. Specifications for standard Vosim modulation will be presented to eliminate future guesswork in evaluating adjacent channel interference by laboratory measurements.

SESSION 3*

MON. 2:30–5:00 P.M.

WALFORD-ASTORIA
JADE ROOM

Propagation

Chairman: P. Newman, *Air Force Cambridge Research Lab., Cambridge, Mass.*

3.1. The Refractive Index of the Atmosphere as a Factor in Tropospheric Propagation Far Beyond the Horizon

R. E. Gray, *Federal Telecommunication Labs., Nutley, N. J.*

Transmission loss measurements have shown that a close correlation exists, in tropospheric scatter propagation, between the index of refraction of the atmosphere and path loss. The exceptional values of transmission loss, which occur for, say, 10 per cent of the time, are shown to be chiefly due to abnormal variations with height of the refractive index; measurements indicate, however, that the monthly median value of transmission loss is a function of the average monthly value of the surface refractivity on the transmission path. Thus, with tropospheric scatter propagation, the transmission loss over a given path is a function of the surface value of refractive index, as measured on the transmission path, and of the variation of this index with height.

3.2. Attenuation and Fluctuation of Millimeter Radio Waves

C. W. Tolbert and A. W. Straiton, *Elec. Eng. Research Lab., University of Texas, Austin, Texas*

Radio propagation measurements at a wavelength of 4.3 mm over a 61-mile path between Pikes Peak and Mount Evans are reported. An estimate of the water vapor and oxygen absorption is made from the variation of the attenuation with moisture content. The spectra and rms of the fluctuations of the millimeter waves are compared to those of the 3.2-cm waves recorded simultaneously. Instantaneous signal levels of the two wavelengths during a shower are compared. The results of these measurements are interpreted in terms of various millimeter wavelength measurements previously made by this Laboratory and by others.

3.3. New Evidence of Anomalous Transequatorial Ionospheric Propagation

O. G. Villard, Jr., S. Stein, and K. C. Yeh, *Radio Propagation Lab., Stanford University, Stanford, Calif.*

The existence of anomalous north-south propagation across the equator occasionally reported by amateurs has recently been verified by means of a rotating-antenna oblique ionospheric sounding station using the ground back-scatter technique and located in the West Indies. During the afternoon and evening hours of virtually every day, echoes were observed which are believed to be a consequence of one-hop transequatorial transmission over distances varying between 6000 and 8000 km. The observed maximum usable frequency was appreciably higher than that which would be predicted on the basis of vertical sounding measurements.

An explanation of this effect is proposed, which takes into account the remarkable increase in virtual height reported around 1800 hours local time at equatorial sounding stations. It is suggested that the observed transequatorial propagation takes place by two successive ionspheric reflections at the northern and southern edges of this equatorial bulge in the ionosphere. The unusually high muf's observed may be explained in part by the operation of the secant law in the case of a warped ionosphere, and in part by the fact that the two reflections occur well to the north and to the south of the geomagnetic equator.

3.4. Foreground Terrain Effects on Overland Microwave Transmissions

L. G. Trolese, *Smyth Research Associates, San Diego, Calif.*

Small terrain irregularities can produce large variations in field strength. Measurements taken at 3300 and 9375 mc on a 46.3-mile non-optical link demonstrate that proper antenna siting can increase the signal by 15 to 30 db. A method of making propagation measurements to determine the effect of terrain irregularities on microwave links is described. The coupling between atmospheric refraction and irregular terrain is discussed.

3.5. Mountain Obstacle Measurements

R. E. Lacy, *Signal Corps Eng. Labs., Fort Monmouth, N. J.*

During 1955 several hundred paths were tested for mountain obstacle transmission loss in approximately 40 different locations in California. Thorough investigations were made of representative frequencies from 50 to 500 mc. Limited measurements were made at 900 and 1800 mc. Almost without exception, all paths planned provided the anticipated obstacle-gain phenomena. Suitable techniques were evolved whereby these phenomena may be used to extend radio communication ranges in mountainous areas along non-line-of-sight radio paths. It has been shown that 20–30-db reduction in comparison to tropospheric scatter paths in path loss is readily obtainable in mountainous areas. In comparison with smooth earth paths, the obstacle gain figures are in the order to 70 to 80 db. A reliable and accurate means for computing the mountain obstacle transmission loss, and a simplified siting procedure were developed.

3.6. Passive Repeater Using Double Flat Reflectors

R. F. H. Yang, *Andrew Corp., Chicago, Ill.*

A means of transmitting a microwave signal over an obstruction such as a mountain by using double passive repeaters is reported. It consists of two large, flat, rectangular reflectors nearly parallel to each other with an angle of 45° or less between the beam and the normal to the surface. The propagation loss through the reflectors is given. Analysis of a typical 7-kmc system shows that this scheme is practical. Its advantages over other existing systems are discussed. A brief comparison between this system and one using forward-scatter propagation through the troposphere is presented.

SESSION 4*

MON. 2:30–5:00 P.M

WALDORF-ASTORIA
SERT ROOM

Ultrasonics Engineering I—An Educational Session

Chairman: W. G. Cady
Pasadena, Calif.

4.1. Training in Ultrasonics

* Sponsored by the Professional Group on Antennas and Propagation. To be published in Part 1 of the 1957 IRE Convention Record.

* Sponsored by the Professional Group on Ultrasonics Engineering in cooperation with the Acoustical Society of America. To be published in Part 9 of the 1957 IRE Convention Record.

F. V. Hunt, *Div. of Eng. and Appl. Phys., Harvard University, Cambridge, Mass.*

W. P. Raney, *Harvard University, Cambridge, Mass.*

4.2. Ultrasonic Analysis

T. F. Hueter, *Acoustics Lab., Massachusetts Institute of Technology, Cambridge, Mass.*

4.3. Some Fundamentals of Transducer Design for the Sonic and Ultrasonic Range

F. Massa, *Massa Labs., Inc., Hingham, Mass.*

4.4. The Ethics, Standards, and Objectives of the Recently Formed Ultrasonics Manufacturers Association

S. R. Rich, *The General Ultrasonics Co., Hartford, Conn.*

This educational session on ultrasonics has been organized through the cooperation of the Acoustical Society of America and the Institute of Radio Engineers. A close liaison has been established between the Committee on Sonic and Ultrasonic Engineering of the Acoustical Society of America and the Professional Group on Ultrasonics Engineering of the IRE. The recently organized Ultrasonic Manufacturers Association has shown a fine spirit of friendliness and cooperation with both of these organizations.

The program for the educational session will emphasize four important aspects of the rapdily expanding field of ultrasonics: 1) The fundamental training for professional activity in this field, 2) a broad view of the applications, both academic and industrial, as shown in problems demanding ultrasonic analysis, 3) the chief component part (the transducer) of all ultrasonic equipment, and finally 4) the role which the manufacturer assumes in promoting the science of ultrasonics. Outstanding authorities will speak on each of the four aspects.

SESSION 5*

MON. 2:30–5:00 P.M.

WALDORF-ASTORIA GRAND BALLROOM

Aeronautical Electronics

Chairman: J. V. N. Granger, *Granger Associates, Inc., Menlo Park, Calif.*

5.1. A New Aircraft Static Discharger

R. L. Tanner, *Stanford Research Institute, Menlo Park, Calif.*

Aircraft flying through ice clouds or snow are charged to high potentials by the impact of the ice particles. The charge thus deposited is relieved by corona discharges occurring at the aircraft extremities. These discharges produce the rf noise known as "precipitation static" which couples into and frequently disables aircraft radio systems.

The precipitation charging rate rises rapidly with speed, and wick dischargers, intended to discharge this current noiselessly, are of little value on modern aircraft because of their limited discharge capacity, their aerodynamic drag, and their vulnerability to deterioration in high-speed airstreams.

The present paper describes a discharger employing a new principle for decoupling the noise produced in the discharges. Dischargers using the principle have much increased current capacity and can be flush mounted, making them suitable for installation on jet aircraft.

5.2. Thermal Design of Commercial Airborne Electronic Equipment

H. M. Passman, *Collins Radio Co., Cedar Rapids, Iowa*

This paper deals with the test techniques necessary to thermally evaluate commercial airborne electronic equipment. Special emphasis is placed on how to instrument equipments for temperature, air static pressure, and air flow quantity measurement, including instrumentation of vacuum tubes for bulb hot-spot temperature measurement.

As a result of the thermal test program outlined above, design improvements have been put into practice. These improvements are described. They include: 1) Dust cover ventilation design for both forced cooled and nonforced cooled equipments, 2) location of components, 3) use of improved tube shields, 4) new forced air cooling tube sockets, 5) effective forced air cooling of modulized equipments, and 6) other.

5.3. The New Look in Electronic Controls

R. J. Meyer, *Collins Radio Co., Cedar Rapids, Iowa*

With the coming of performance jet aircraft, the modern airplane has developed into an exceedingly complex machine. This complexity has imposed an exacting and difficult task upon its pilot.

To implement improved operation of electronic controls and reduce pilot errors, human engineering principles have been applied to design criteria. Horizontal digital type counter presentations have been utilized in all frequency and channel displays. Numerals and/or letters are simple in design, and employ large, easily-read horizontal characters. Location, shape, and type of movement of each control knob have been carefully chosen to accomplish the desired action with a minimum delay or chance of error, even under operating conditions in which a pilot is wearing a full pressure suit.

Application of human engineering principles to electronic controls has resulted in vastly improved performance and a corresponding reduction in pilot errors. Integration of several control panels into one central panel results in a reduction of critical panel area required and in addition retains the advantage of improved performance. Future applications will undoubtedly open new approaches to improve visual displays and error-free operation.

5.4. Field Test Equipment for Airborne Radar

W. W. Keith and F. E. Sears, III, *Raytheon Manufacturing Co., Wayland, Mass.*

The use of skilled electronics personnel is minimized, equipment reliability is improved, and down time is reduced by means of an adequate field test equipment program. An example is given of a field test equipment for an airborne radar which features: 1) Runway equipment, for quick preflight tests at the aircraft without use of an oscilloscope, and for maintenance tests to localize trouble to a major unit of the radar, and 2) hangar equipment, for go-no go tests of hermetically sealed modules such as the IF amplifier, afc and servo-amplifier. Self-testing circuits detect failure of the test equipment.

5.5. Hazardous Environmental Factors and Effects Related to High-Supersonic-Speed Bomber Defense Problems

I. Katz, *General Electric Co., Ithaca, N. Y.*

Postulation, design, and performance of defensive subsystems depends upon the functional and organic compatibilities of equipment with the prevailing physical environment. Flight at high supersonic speeds introduces many environmental factors and effects that decisively influence the choice of system and critically affect the performance and reliability of equipment. Extremes of temperature, pressure, radioactivity, acoustical noise, motion, vibration, shock, and certain chemical changes, as functions of both natural and induced physical conditions, constitute the hazardous environment.

The intriguing effects of flight operations and associated propulsive power levels on the physical environment are discussed with a view toward defining, in engineering terms and numbers, the challenging physical conditions that equipment will encounter and with which it must cope. Suggestions are given for achieving practical compatibility and for striking design compromises that implement attainment of realistic objectives.

SESSION 6*

MON. 2:30–5:00 P.M.

NEW YORK COLISEUM MORSE HALL

Multiplex Communications System

Chairman: J. Z. Millar, *Western Union Telegraph Co., New York, N. Y.*

* Sponsored by the Professional Group on Aeronautical and Navigational Electronics. To be published in Part 8 of the 1957 IRE Convention Record.

* Sponsored by the Professional Group on Communications Systems. To be published in Part 8 of the 1957 IRE Convention Record.

6.1. Signal Mutilation and Error Prevention on Short-Wave Radio-Teleprinter Services

J. B. Moore, *RCA Communications, Inc., New York, N. Y.*

Noise and fading conditions on such services differ markedly from those generally assumed in analyzing telegraph or data-handling services over wire lines; the problem being rendered particularly difficult by the wide range of types, durations, and rates of signal mutilation. The most successful system for mutilation detection and error prevention is the so-called "7-Unit" constant-ratio code and basic system plus Automatic-RQ. Observational data and theoretical analyses from various sources, indicate improvement ratios—reduction in number of character transpositions—ranging from 20/1 to 1000/1 to 50,000/1 for signal-mutilation rates from 4 in 10 to 1 in 100 to 1 in 1000 characters respectively.

6.2. Time-Division Multiplex System with Addressed Information Packages

R. Filipowsky and E. Scherer, *Westinghouse Electric Corp., Baltimore, Md.*

A digital multiplex communication system is described wherein the channels are combined in asynchronous time division; there is no fixed and predetermined sequence by which the individual transmission intervals would be allotted to the various channels. On the contrary, each transmission interval is electronically "auctioned" and is allotted to the highest bidder, *i.e.*, to the channel having instantaneously the most urgent need for forwarding its message or a fraction thereof. The receiver has no knowledge to which channel the information within one transmission interval should be directed, unless each interval will carry its own address. One interval may contain one quantized sample only or a larger amount of time compressed information, *i.e.*, one information package.

6.3. A New Time-Division Multiplex System

W. J. Bieganski and L. M. Glickman, *Radio Corp. of America, Camden, N. J.*

A new time division, pulse position modulation, voice multiplex system has been developed. The system is completely transistorized. Transistor matrix techniques are used in the distributor, resulting in highly accurate timing without any adjustments. A phase lock loop serves to synchronize the demultiplexer to the multiplexer with greatly improved noise performance. Two versions of multiplex equipment, with different channel capacities, are described: 7-channel equipment, with provision for combining for 14-channel use, and 23-channel equipment, with provision for combining for 46-channel use. Drop and insert facilities are provided at reshapers. Transistor circuitry constituting the system is described in some detail.

6.4. 58-Channel PCM System

S. M. Schreiner, *Federal Telecommunication Labs., Nutley, N. J.*, and A. R. Vallarino, *Precision Technology, Inc., Livermore, Calif.*

This paper describes a 48-channel pulse code modulation system (the AN/TCC-15) employing instantaneous compandors and 6-bit (64-level) cathode-ray-type coding tubes. The equipment accepts 47 telephone channel inputs and provides a binary-coded output signal capable of transmission over any 2.5-mc video circuit. The coding is accomplished by two 24-channel coders, each using a coding tube which generates a CP code and a high-speed flip-flop which translates the signal to a true binary code. The two-coder output signals are then combined before transmission. One hundred per cent standby of all common 48-channel equipment insures 24-channel operation in the event of any failure. The over-all system provides 47 audio channels with a 300-3600-cps pass band, an audio s/n greater than 60 db, and an interchannel crosstalk of better than −53 db. Recent field tests indicating a mean life of 2500 hours between failures attest to the high reliability designed into the equipment.

6.5. Portable Multichannel 11,000 MC Radio Link

H. Engelmann, H. A. French, M. W. Green, and J. Harvey, *Federal Telecommunication Labs., Nutley, N. J.*

A portable 7-channel telephone relay link operating in the 9 to 11-kmc region using time-division multiplex pulse position modulation is described. Printed circuitry and the use of miniature type components have been used to make possible the construction of an equipment $23\times21\times12\frac{1}{2}$ inches in size and weighing less than 125 pounds, containing multiplex equipment, transmitter, receiver, and antenna, all in one package.

The electrical design is described and the mechanical construction used to obtain a high space utilization factor is shown.

Applications and field experience obtained using the first developmental models is detailed.

SESSION 7*

MON. 2:30–5:00 P.M.

NEW YORK COLISEUM MARCONI HALL

Information Theory—Coding and Detection

Chairman: W. B. Davenport, Jr., *Lincoln Labs., Massachusetts Institute of Technology, Lexington, Mass.*

* Sponsored by the Professional Group on Information Theory. To be published in Part 2 of the 1957 IRE Convention Record.

7.1. Optimum Decision Feedback Systems

B. Harris, A. Hauptschein, and L. S. Schwartz, *College of Eng., New York University, New York, N. Y.*

This paper studies the problem of reducing decision risk in the extraction of signals from noise for the case of decision feedback in which the transmitter is called upon to repeat signals corresponding to doubtful observations. The objectives of the paper are twofold: 1) To develop a theory of decision feedback systems by means of which the optimum conditions of operation in the least-cost sense can be specified, and 2) to demonstrate that integration or a simple parity check for interpreting doubtful observations is less efficient in its use of the fundamental communication parameters of power, bandwidth, and time than decision feedback.

7.2. Sequential Decoding for Reliable Communications

J. M. Wozencraft, *Massachusetts Institute of Technology, Cambridge, Mass.*

A code for constant-rate communication over binary symmetric channels is presented. For coding, parity checks over subsets (selected by convolution) of preceding information digits are inserted between information digits. For decoding, the first information digit is determined by progressively discarding as improbable all possible messages inconsistent with its correct value. The discard probability threshold is varied to minimize both the error-probability and the average number of computations. The entire procedure is then iterated. The error probability is shown to decrease exponentially with code length, while the average number of binary computations per bit grows approximately linearly. Rates near one-half capacity appear feasible.

7.3. A Non-Mean-Square-Error Criterion for the Synthesis of Optimum Sampled-Data Filters

A. R. Bergen, *Dept. of Elec. Eng., Columbia University, New York, N. Y.*

This paper presents a non-mean-square-error criterion for designing optimum linear finite memory filters for the continuous prediction and smoothing of sampled data. It is suggested by, and approximates, a generalized tolerance criterion whose use, while desirable in many applications, is excessively complicated. The new criterion simplifies the design considerably for inputs which are the sampled sum of Gaussian noise and a nonstationary message; the message consists of sections of finite duration having a polynomial variation with time alternating with arbitrary transitions. The design procedure is straightforward, requiring only a most elementary description of the inputs and results in fairly simple filter structures.

7.4. Message Redundancy vs Feedback for Reducing Message Uncertainty

W. B. Bishop and B. L. Buchanan, *Air Force Cambridge Research Center, Bedford, Mass.*

The use of redundancy in the coding of digital messages is generally directed toward overcoming the effect of a very small number of errors. The use of a small amount of feedback can be effective in reducing the uncertainty concerning the correctness of messages. Two assumptions normally made in these cases are: 1) The probability of error in any digit is independent of errors that occur elsewhere, and 2) no errors occur in the feedback path. There is a large class of digital communication systems for which these assumptions do not hold; the advantages of feedback for this class are compared with the advantages obtainable by using selective redundancy without feedback. For the class of communication systems in which the feedback channel is the same as the forward channel, it is proved that message uncertainty is reduced more by the transmission of $M+C$ digits in the forward direction (where M represents the number of message digits and C represents the number of redundant digits) than by the transmission of M digits in the forward direction and C in the reverse. The probability distributions of feedback termination and the message uncertainty at the time of termination are derived for systems in which feedback for any message is continued until the received feedback message agrees with the message sent. It is also shown that a new statistical error-checking procedure has advantages over other forms of redundancy when the probabilities of errors are within certain defined limits. A means of implementing this statistical error-checking procedure with simple electronic equipment is described.

7.5. The Analysis of Post-Detection Integration Systems by Monte Carlo Methods

R. Dilworth, *California Institute of Technology, Pasadena, Calif.*, and E. Ackerlind, *Radio Corp. of America, Los Angeles, Calif.*

By means of a random sampling procedure the cumulative probability distribution of threshold crossings has been determined for the cases of: 1) IF amplifier, square-law detector, and post-detection integration, and 2) IF amplifier, linear detector, and post-detection integration. Various signal to noise ratios and various durations of signal are considered.

Random samples are selected from a population whose distributions are computed at the output of the detector for both cases and are processed in a manner determined by the post-detection integration filter characteristics.

Comparison is made with results obtained by other methods.

SESSION 8*

MON. 2:30–5:00 P.M.

* Sponsored by the Professional Group on Electron Devices. To be published in Part 3 of the 1957 IRE Convention Record.

NEW YORK COLISEUM FARADAY HALL

Solid State Devices

Chairman: W. J. Pietenpol, *Bell Telephone Labs., Murray Hill, N. J.*

8.1. A New High-Frequency N-P-N Silicon Transistor

A. B. Phillips and A. M. Intrator, *General Electric Co., Syracuse, N. Y.*

This paper describes a newly-developed meltback diffused base transistor having a low series saturation resistance and a nominal alpha cutoff of 25 mc, which was designed for application in high-frequency linear amplifiers and general purpose switching circuits. A general description of the device is given and the theory of obtaining a p base region by means of the diffusion-meltback technique is discussed

Data are presented showing the variation of device parameters with temperature, frequency, current, and voltage. The large signal behavior of the device is shown and its performance in switching circuits is described.

8.2. Noise Figures in Semiconductor Dielectric Amplifiers

J. M. Walker, R. E. Smith, and E. M. Williams, *Carnegie Institute of Technology, Pittsburgh, Pa.*

Noise measurements on amplifiers utilizing the voltage-dependent junction capacitance of germanium diodes as the nonlinear element in a series resonant circuit are described. Noise measurements on the diode amplifier are discussed in conjunction with an equivalent circuit which is used to explain the noise measurements and the noise figure. The important noise components are shown to be attributable to noise from the diode and noise amplitude and frequency modulation in the carrier. Low-temperature noise measurements on the amplifier and the diode parameters are presented together with a description of other methods of improving and optimizing the noise figure.

8.3. Determination of Thermal Resistance of Silicon Junction Devices

H. C. Lin and R. E. Crosby, Jr., *CBS-Hytron, Semiconductor Operations, Lowell, Mass.*

The usual method of determining the thermal resistance of germanium junction devices is to measure the variation of the reverse saturation current which increases as the junction temperature rises. This method cannot be used with silicon junction devices, as the leakage current rather than the saturation current of these devices is the major portion of the reverse current. In the system described here the forward characteristics vs temperature rise are measured. This is possible as the forward voltage drop of a silicon junction device varies with temperature in a manner that is both predictable and relatively simple to measure. Theoretical results and experimental data are plotted and compared at various forward currents There is a very good agreement The operation of the circuit is also described.

8.4. An Alloy-Type Medium Power Silicon Transistor

H. G. Rudenberg and G. Franzen, *Transitron Electronic Corp., Wakefield, Mass.*

This silicon transistor was developed to evaluate an alloy fusion process for producing a medium power audio transistor for low voltage airborne use operating above 100°C. The 10-watt unit described has a power gain of 20 db and weighs less than ½ ounce. Saturation voltages have been reduced below 2 volts. Internal heat dissipation is removed by thermal contact with the chassis heat sink. Some problems of design and processing affecting the ultimate characteristics will be discussed. Simplified test methods and a power converter utilizing this transistor will also be presented.

8.5. A New Semiconductor Device

C. A. Aldridge, *General Electric Co., Syracuse, N. Y.*

This paper presents the basic biasing modes of operation for a new type of semiconductor amplifying device. In addition, the 24 basic signal-flow configurations are shown. Since the number of usable circuit configurations is quite large, a system is proposed for identifying the particular configuration in an organized manner It is shown how each of the basic circuit forms can be realized by any one of severa circuit connections, depending on the associated components used.

The mechanical and electrical characteristics of the new device are described. It is also shown that significant circuit economies are achieved.

8.6. Cadmium Sulfide Photocapacitors

F. Gordon, Jr., P. A. Newman, J. Handen, H. Jacobs, *Signal Corps Eng. Labs., Fort Monmouth, N. J.*, and A. Ramsa, *CBS Labs., New York, N. Y.*

A description of the photocapacitor, including the preparation of the photosensitive materials and the assembly of the device, is given. Methods and equipment for evaluation of the device are described along with some results. A brief discussion of the possible mechanisms responsible for this change in capacitance with radiation is given. An attempt is made to correlate the theoretical and experimental results. Some of the possible applications are indicated along with the potentialities and limitations of the present device.

Changes in capacitance for a given dielectric material in the photocapacitor are dependent upon the wavelength and intensity of the light source and the frequency and magnitude of the applied voltage. The magnitude of these changes ($\Delta c/c$) and the variation in magnitude and response time with the variation of the above parameters is illustrated. Also shown is performance variation with different impurities and impurity concentrations and the method of preparation of these materials

SESSION 9*

TUES. 10:00 A.M.–12:30 P.M.

WALDORF-ASTORIA STARLIGHT ROOF

Automatic Control—General

Chairman: G. S. AXELBY, *Westinghouse Electric Corp., Baltimore, Md.*

9.1. Digital Controllers for Feedback Systems

J. R. RAGAZZINI, *Columbia University, New York, N. Y.*

A digital controller for a feedback control system is a computer which accepts a sequence of numbers at its input and delivers a processed sequence of numbers at its output. The implementation of the computer may be completely analog or digital, or a combination thereof, as will be shown by typical designs. The output sequence of the controller may be generated at a rate equal to or at a multiple of the input sequence rate. For linear systems, it is possible to program the computer to cause the control system to have a desirable over-all prototype response subject to certain theoretical limitations. For computers in which the output data rate is a multiple of the input rate, faster response can be achieved. The theory of sampled-data systems is applied to the synthesis of the digital controller program which will produce these desirable prototype response functions. The theoretical restrictions which limit the choice of response functions are pointed out. Examples of typical designs which illustrate the theory are given

9.2. Sampling in Linear and Nonlinear Feedback Control Systems

J. KUKEL, *Servomechanisms, Inc., Hawthorne, Calif.*

The Z transform has been popularized by Ragazzini and Zadeh at Columbia University and Linvill and Salzer of M.I.T The usual approach to Z transformation is through the Laplace transform. However the Laplace transform and its associated limitations can be completely by-passed. If the time domain differential equation is integrated, the appropriate numbers of times and the integrals changed to the convolution form, a time domain convolution equation with initial conditions results. The Z transform of the convolution equation can be taken directly. Use of tabulated tables similar to the Laplace transform are most helpful. The convolution and the Z-transform operations allow the analysis or synthesis of continuous and sampled-data control systems which are linear or nonlinear. Nonlinear systems are included since the Laplace transform, which is limited to linear systems, is avoided.

The procedure can cover higher order and variable forcing function nonlinear systems. It does not have the limiting restrictions of the phase trajectory and the describing function technique. Although approximations are made in the substitution of continuous functions by their sampled form, the cumulative error in transient analysis can be made small by judicious choice of sampling interval. Steady-state analysis is treated as repeated transient and periodicity is assumed. Exactness occurs in period determination. Some error occurs in waveform amplitude. The error here, as before, is reduced by choice of smaller sampling interval.

9.3. The Role of Automatic Control in the Modification of Aircraft Dynamic Flight Characteristics

W. N. TURNER, *Hughes Aircraft Co., Culver City, Calif.*

The basic ideas and methods used in the determination of aircraft dynamic flight characteristics are described, and a physical description of the several typical primary dynamic flight modes of aircraft is given. The reasons for some of the undesirable features of these modes are indicated, and the manner in which automatic control techniques can be utilized to modify and improve the flying qualities is illustrated.

9.4. Solution of Statistical Problems by Automatic Control Techniques

R. L. COSGRIFF, *Dept. of Elec. Eng., Ohio State University, Columbus, Ohio*

It has been widely accepted that many processes in the broad field of science essentially can be classified as closed-loop systems. Many of the problems encountered in these fields are essentially statistical in nature and, as a result, have not been analyzed using the differential equation approach, however autocorrelation and spectral density approach have been used. It is demonstrated that the differential equation approach can be used to determine the expected behavior of many of the "statistical type systems."

9.5. The Design of Optimum Filters and Predictors

C. W. STEEG, *Dynamic Analysis and Control Lab., Massachusetts Institute of Technology, Cambridge, Mass.*

The solution of many automatic control problems depends upon obtaining some functional of a signal component of a measured quantity when the measurement contains both signal and noise. When the input to the system consists of a random signal plus a random noise, both derived from linear, time-varying, intergrodifferential operations on uncorrelated noise sources, a technique can be applied to simplify the design of filters and predictors. This technique involves the choice of a particular configuration for the optimum filter; a proof is given that knowledge of a certain operator in this configuration is sufficient to allow the determination of a significant class of optimum systems. Details of the method are presented to provide means for circumventing practical difficulties encountered in the actual design of optimum systems based on the earlier techniques devised by Weiner.

* Sponsored by the Professional Group on Automatic Control. To be published in Part 4 of the 1957 IRE CONVENTION RECORD.

SESSION 10*

TUES. 10:00 A.M.–12:30 P.M.

WALDORF-ASTORIA ASTOR GALLERY

Navigation

Chairman: R. C. NEWHOUSE, *Bell Telephone Labs., Whippany, N. J.*

10.1. A Realistic Radar Clutter Simulator

J. ATKIN, H. J. BICKEL, AND M. R. WEISS, *Dept. of Elec. Eng., Columbia University, New York, N. Y.*

The need for an entirely realistic search radar simulator arises in the design and testing of automatic detection, track-while-scan, beam-splitting, and other data-processing systems. Equipment capable of simulating the statistical and systematic characteristics of echoes received from isolated targets has been described in the literature. The authentic simulation of radar echoes from wooded terrain, meteorological phenomena etc., has been hampered by the difficulty associated with the reproduction of the particular statistical and spectral properties of reflections from this class of "extended targets." The device, whose theory and implementation will be described, generates "sweeps" of Rayleigh distributed clutter having video bandwidth in range, but only audio (or sub-audio) bandwidth at constant range as a function of time. The audio fluctuation rate of the video at constant range duplicates the high correlation in real clutter amplitudes received during a number of consecutive sweeps; this differentiates such signals from ordinary noise. The key components in the clutter simulator are an ultrasonic delay-line memory and a 30-mc Gaussian noise source.

10.2. A Precision Multipurpose Radio Navigation System

W. N. DEAN, R. L. FRANK, AND W. P. FRANTZ, *Sperry Gyroscope Co., Div. of Sperry-Rand Corp., Great Neck, N. Y.*

This paper describes a pulsed hyperbolic navigation system similar to Loran, but achieving greater range, accuracy, and reliability over land and sea at all altitudes through the use of ground-wave cycle-phase-measuring techniques on a 100-kc carrier frequency.

Part I describes the general features of the system, analyzes the effect of station geometry on accuracy and interprets the results of extensive field tests. The system is shown to have sufficiently low altitude coverage and accuracy for point-to-point helicopter navigation coupled with range sufficient for transcontinental jets and transoceanic air and surface navigation. These characteristics can be obtained with very few transmitting stations, compared with other type systems

Part II discusses the choice of carrier frequency including calculations and measure-

* Sponsored by the Professional Group on Aeronautical and Navigational Electronics. To be published in Part 8 of the 1957 IRE CONVENTION RECORD.

ments of propagation parameter such as noise levels, groundwave attenuation, skywave attenuation and delay, groundwave phase stability, and dispersive effects. Observations of groundwave phase variations apparently due to weather are reported.

Part III outlines the instrumentation techniques utilized to achieve time-difference measurement to a few parts per million, including automatic pulse envelope time difference measuring systems, and cycle-phase measuring systems incorporating cross-correlation detection and narrow banding. Transmitter and antenna designs to produce necessary sharp pulses are also described.

10.3. Some Final Approach System Requirements for High Landing Rates

F. H. Battle, Jr., *Airborne Instruments Lab., Inc., Mineola, N. Y.*

The density and character of air traffic in prospect for the near future substantiate a goal of two instrument landings per minute, with a 4:1 range of approach speeds. Feasibility of scheduling landings at such a rate depends on a short final approach to avoid overtake, and on completion of turn-on during the final minute of flight. Horizontally-curved, rate-stabilized paths such as are obtained with flight directors, are analytically extended to their limits of usability with wide-sector final-approach aids. The practical maximum of horizontal coverage to be required of the final-approach system is derived.

10.4. General Characteristics of a 1000-MC Instrument Landing System

A. Casabona, *Federal Telecommunication Labs., Nutley, N. J.*

By Air Force contract, the Federal Telecommunication Laboratories developed a cw localizer and glide slope, operating in the 960-mc to 1215-mc range, whose description and test forms the subject of this paper. The data indicate a substantial improvement in site freedom due mainly to the specular nature of 1000-mc reflections as compared to reflections at lower frequencies.

The cw localizer was later modified for pulsed operation which permitted integration of the landing signal with other navigation functions. The resulting equipment provides localizer guidance and distance to touchdown on a common transmission from the ground and utilizes a common airborne receiver.

The techniques discussed in the paper can be applied to the design of a landing system which offers great reduction in size of equipment, excellent mobility, increased freedom in siting, and integration with other navigation aids.

SESSION 11*

TUES. 10:00 A.M.–12:30 P.M.

WALDORF-ASTORIA JADE ROOM

* Sponsored by the Professional Group on Broadcast Transmission Systems. To be published in Part 7 of the 1957 IRE Convention Record.

New Broadcast Developments

Chairman: C. E. Smith, *Cleveland, Ohio*

11.1. An Analysis of Packing Density of Information in High-Velocity Transverse Video Magnetic Recording

W. Selsted, *Ampex Corp., Redwood City, Calif.*

Coincidences exist between the nature of television synchronizing and video signals, and the peculiarities of fm systems employing high ratios of modulating frequency to carrier frequency, and high ratios of deviation to carrier. These can be exploited to compress the television frequency range into a band which is compatible with the capabilities of a magnetic recorder using high tape-to-head relative velocities. The means by which this exploitation is accomplished also make possible desirable manufacturing and maintenance tolerances.

11.2. High-Light Aperture Equalizer

M. V. Sullivan, *CBS Labs., New York, N. Y.*

The present method of aperture equalization of a television signal has one severe limitation. This is that the high-frequency noise in the picture signal is increased along with the high-frequency signal information. The amount that the high-frequency fine detail can be increased is limited by the undesired noise.

The "High-Light Aperture Equalizer" provides more equalization without increasing the noise in the same proportion. This feature is obtained by dividing the video signal into two parts with respect to amplitude, and equalizing the portion that is relatively free of noise.

The circuit has been successfully tested in monochrome and color television.

11.3. Single-Sideband Broadcast Developments

L. Kahn, *Kahn Research Labs., Freeport, N. Y.*

A new system for allowing an increase in the number of AM broadcast channels is described, which is called "Compatible Single-Sideband." This system would require use of a transmitter adapter but does not necessitate any change in the home receiver.

The advantages of this system may be outlined as follows: 1) The signal occupies approximately one-half the spectrum as does a conventional AM double sideband signal. This reduction in bandwidth provides a means for reducing adjacent and cochannel interference; 2) reduction in fading distortion thus improving nighttime coverage; and 3) reduction in bandwidth also allows an improvement in signal-to-noise ratio of 3 db *or* approximately double the high-frequency response of typical home receivers.

A block diagram of an adapter suitable for use with any standard AM transmitter is discussed.

11.4. UHF High-Power Transmitting Developments

J. E. Young, L. L. Koros, and I. Martin, *Radio Corp. of America, Camden, N. J.*

This paper treats development of transmitting equipment for the uhf portion of the spectrum involving high-power transmitters and high-gain antenna design. Information will be given concerning tubes having 25-kw power handling capabilities in this portion of the spectrum and trends in this area of development. A summary of power measurements is contained and experience with commercial application at an existing uhf station is treated.

11.5. A Dynamic Standard for Color Television Systems

R. C. Kennedy, *National Broadcasting Co., New York, N. Y.*

This paper relates to the possible secondary usages which may be made of the time required for the beam in a television picture tube to return from the bottom to the top of the picture.

Heretofore, no application of this so-called retrace time has been attempted. However, it has been found that several different kinds of information may be transmitted while the actual television show is in progress.

One of the most important sets of signals which may be sent during this unused time enables the engineer to evaluate the performance of the complete television signal path from camera to the transmitter and receiver. These signals permit correct adjustment of signal strength, of the monochrome and color portions of a television program at successive points along the route of the show.

The result of having such information sent along with the program is to improve the received signal and enable the viewer to more accurately adjust his receiver.

SESSION 12*

TUES. 10:00 A.M.–12:30 P.M.

WALDORF-ASTORIA SERT ROOM

Ultrasonics Engineering II—Technical Session

Chairman: J. W. Horton, *U. S. Navy Underwater Sound Lab., New London, Conn.*

12.1. Sea Clutter in Radar and Sonar

R. M. Hoover and R. J. Urick *Ordnance Research Lab., Pennsylvania State University, University Park, Pa.*

The surface of the sea back scatters both electromagnetic radiation incident from above and acoustic radiation incident from below. Recent measurements of sound scattering by the sea surface make possible some interesting comparisons between radar sea-clutter and sonar surface reverberation at the same wave-

* Sponsored by the Professional Group on Ultrasonics Engineering. To be published in Part 9 of the 1957 IRE Convention Record.

length. The acoustic data provide the first systematic information about the sonar back scattering coefficient of the sea surface. and give some hints as to the scattering processes that operate. A comparison of sonar with available radar data at approximately the same wavelength indicates that, although the back-scattering cross sections are of the same order of magnitude, there appear to be differences in the effects of frequency, wind-direction, and grazing angle in the two cases.

12.2. Transducer Comparison Methods Based on the Electromechanical Coupling Coefficient Concept

R. S. Woollett, *U. S. Navy Underwater Sound Lab., New London, Conn.*

The electromechanical coupling coefficient (k) has proven to be a valuable unifying concept which facilitates preliminary comparison of different transduction methods, when a choice of transducer types has to be made for a particular application. The fundamental character of the electromechanical coupling coefficient is made evident by its energy definition, while equations relating it to equivalent circuit parameters and the electromechanical constants of the transducer facilitate its practical use.

The important role which the coupling coefficient plays in determining a transducer's performance is brought out by presenting equations for various performance properties, such as bandwidth, efficiency, transducer noise, electrical power factor, and power capacity. Factors influencing k are discussed for two general categories of transducers: body-force and surface-force types; and coupling coefficient formulas are given for simple prototypes of the various transducer classes. Finally, an example is given of comparison of the different transduction methods for a particular application.

12.3. Polarization of Barium Titanate Ceramic

J. G. Froemel, *Gulton Industries, Inc., Metuchen, N. J.*

Polarization of barium titanate ceramic is one of the basic and fundamental properties of the materials and one which few have investigated. The following is a brief description of polarization, polarization procedures, and the methods of evaluating these polarization procedures. Various methods of polarization are presented along with their evaluation.

The resonance antiresonance method has been used by many to evaluate the various piezoelectric and elastic properties of barium titanate ceramics. However, this can lead to serious errors since various modes can add or subtract from the constant wanted. Polarization procedures are rarely given, which can account for the wide variation of such piezoelectric parameter as d_{33}, d_{13}, and others.

The d_{33} can be shown to be nonlinear and of course frequency, field, and time dependent.

A direct method of measuring the piezoelectric coefficients is presented which eliminates or takes into consideration the above items.

The optimum polarization procedure for barium titanate is presented along with a discussion of the failures which make optimum polarization impossible in some cases. Reduction and diffusion in barium titanate have a pronounced effect on the polarization and are described in detail. Methods of eliminating or retarding these are presented.

A brief review of the chemical theory of polarization is also presented.

12.4. Ultrasonic Liquid Level Sensor

R. L. Rod, *Acoustica Associates, Inc., Glenwood Landing, N. Y.*

The ever-present need for a reliable yet simplified liquid level sensor is met using a newly-developed ultrasonic probe. Operating on the principle that an ultrasonic transducer in contact with a liquid presents a terminal impedance appreciably different than obtained when it is purely "air-loaded," the new sensor basically consists of a subminiaturized transducer appropriately mounted in a tank at a preset height. This change of impedance is not affected by characteristics of the liquid. A transistorized electronic control unit external to the tank energizes a relay when the level passes the sensitive face of the transducer with an accuracy of $\pm 1/32$ inch. The complete level sensor, including the transducer and the electronic control, weighs under 12 ounces and consumes only 100 milliwatts during operation. Performance is stable when sensing virtually all liquids at temperatures of from -270°F to 350°F. The sensor is impervious to foam and clinging droplets and is ideally suited to critical applications in airborne gauging and processing control systems requiring highest reliability and accuracy.

12.5. Precision Calibration of Ultrasonic Fields by Thermoelectric Probes

W. J. Fry and F. Dunn, *Bioacoustics Lab., University of Illinois, Urbana, Ill.*

The highly-stable, small, and readily-constructible ultrasonic probe developed and in use at this laboratory for the past five years will be discussed from the point of view of construction calibration, operation, and application.

This transient-type thermoelectric probe, which is currently being used in a number of other laboratories, yields information concerning the pressure amplitude, particle velocity amplitude, and intensity of the ultrasonic field in which it is placed. If the field characteristics are known, the principle of operation of the probe provides a method for determining the absorption coefficient of minute quantities of materials.

12.6. New Magnetostriction Filters for the MF Band

R. T. Adams, *Federal Telecommunication Labs., Nutley, N. J.*

A series of narrow-band filters has been constructed for carrier pick-off in a developmental telephone-carrier multiplex terminal. The filters are used to select clean single-frequency carriers from the harmonics of a 36-kc or 72-kc pulse train.

The resonator element is a simple one-piece H structure, punched from Ni Span "C" sheet giving a double-tuned response shape. In the frequency range from 500 to 900 kc the filters provide 3 to 6-db voltage gain, operating from 30 ohms into a high impedance, with a pass band of 500 cycles and greater than 50-db rejection of adjacent 36-kc harmonics. The experimental units operate over -30 to $+56$°C. with a temperature coefficient of less than 2 ppm/°C. and withstand moderate shock and vibration. A hermetically-sealed case avoids formation of frost on the resonators at low temperature.

SESSION 13*

TUES. 10:00 A.M.–12:00 NOON

WALDORF-ASTORIA GRAND BALLROOM

Engineering Management Viewpoints

Chairman: E. A. Walker, *Pennsylvania State University, University Park, Pa.*

13.1. Education: Academic Training for Engineering Management

E. Shapiro, *School of Industrial Management, Massachusetts Institute of Technology, Cambridge, Mass.*

The trilogy of science, engineering, and population point to an expanding economy in the generation ahead. To manage this expansion wisely requires the preparation of wise managers in increasing numbers. The management education program at the School of Industrial Management is designed to build on a base of science and/or engineering education. The object of the school is to prepare men to take wise and effective action in the management of industrial concerns. The education offered derives from the belief that a successful manager in the modern technological age should understand the principles of science and engineering upon which the application of industry rests. He should know the methods of production and distribution. He should understand as much as possible about himself, the nature of other human beings, and the environment—economic and political—in which he lives. In addition to this body of knowledge, a successful manager should possess the intellectual skill and resilience to deal with the novel situations presented to him by changes in the economic, social, and technological situation.

The philosophy and implementation of these objectives at the School of Industrial Management will be discussed as illustrative of an experiment in management education for engineering.

13.2. Finance: Wall Street Looks at Engineering Management

O. C. Roehl, *Keystone Custodian Funds, Boston, Mass.*

Management is a most important factor in security analysis. *Who* is behind a balance sheet is usually more important than *what*. The quality of a company's management is reflected in the price of its securities. In research and engineering based industries, such as the electronics industry, the quality of a company's engineering management is a most important determinant of a company's success. This fact is realized by investors and more and more attention is being given to evaluating the effectiveness of the engineering and research work of individual companies. While many factors account for the difference in performance of a security, yet the quality of a company's engineering management is often a primary reason why one company outperforms another in the security markets.

* Sponsored by the Professional Group on Engineering Management. To be published in Part 10 of the 1957 IRE Convention Record.

In these days of rapid technological changes, it is most important that the investor limit his investments to the companies with the best engineering and research management.

The factors that institutional investors consider in evaluating engineering management will be discussed and certain case histories will be reviewed to illustrate the role engineering management is playing and has played in determining the market value of the securities in the electronics industry.

13.3. Industry: Development of Engineering Managers Within Industry

E. I. Greene, *Bell Telephone Labs., New York, N. Y.*

SESSION 14*

TUES. 10:00 A.M.–12:30 P.M.

NEW YORK COLISEUM MORSE HALL

Antennas I—General

Chairman: H. A. Wheeler, *Wheeler Labs., Inc., Great Neck, N. Y.*

14.1. On Ferrite Loop Antenna Measurements

J. L. Stewart, *California Institute of Technology, Pasadena, Calif.*

A general discussion relating to the application of small loop antennas with air and ferrite cores is given. A general procedure for simplified testing of ferrite-loaded magnetic-type small antennas is outlined in which radio-frequency radiation performance is expressed in terms of quantities easily measured at audio frequencies. Only a single measurement is needed to characterize the elementary-dipole-type ferrite-loaded antenna. Finally, a number of measurement results are given which apply to the usual rod-type ferrite-loaded loop antenna: measurement parameters cover a broad range of core lengths and diameters. It is found that typical ferrite-loaded loops have little electrical advantage over air loops although the packaging advantage of ferrite loops may be significant.

14.2. Ground Antenna Phase Behavior in a Differential Phase Measuring System

I. Carswell and C. Flammer, *Stanford Research Institute, Menlo Park, Calif.*

A tracking system which measures distance by comparing the phase of signals arriving at a pair of spaced receiving antennas from a common source remains accurate when the signals have undergone identical phase distortions. The receiving antennas of such a system are normally mounted on a large ground plane to minimize multipath reflection errors at low elevation angles. This paper describes a study made of the effect of ground constants and ground plane size on the amplitude and phase of the electric field above a ground plane surrounded by lossy dielectric. Rapid phase shift near glancing incidence is found to be a function of elevation angle ground reflection coefficient and ground plane size. Results may be used to estimate tracking error in a differential phase measuring system.

14.3. Limits on the Information Obtainable from Antenna Systems

W. White, *Airborne Instruments Lab., Mineola, N. Y.*

This paper starts with a review of the information obtainable from simple antennas such as radar dishes. The hopelessness of various super gain or super directivity proposals is demonstrated by an application of the sampling theorem. It is also shown that the information obtainable is profoundly affected by the *apriori* information available.

The paper continues to a study of more elaborate antenna systems. It is shown how the Mills Cross antenna used in radio astronomy is related to the separate beams of a V-beam radar or the use of separate search and height finding radars. Various interferometer techniques are also discussed and it is shown that there is an important difference between the radio astronomy case of incoherent radiation and the radar case with its coherent reflections.

14.4. Antenna Problems In Radio Astronomy

R. N. Bracewell, *Stanford University, Stanford, Calif.*

The design application of antennas with microsteradian beams such as the one under construction at Stanford University merit refined analysis of the type which has become familiar in the one-dimensional case in information theory.

Just as a waveform whose spectrum is band limited is fully represented by certain spaced samples, so an antenna array whose beam will be used to explore emitting or reflecting objects of limited extent may be whittled down to a certain lattice with no loss of information.

Array tapering raises questions analogous to optimum design of filters for fidelity and freedom from overshoot. A compromise between fineness of detail in the source or target and freedom from spurious effects due to side lobes is shown to depend on the spatial spectrum of the source and of the noise.

Beam-splitting techniques permit further whittling away of the antenna structure but introduce problems. Design details of the Stanford microwave spectroheliograph will be discussed.

14.5. High Altitude Breakdown Phenomena

J. Ashwell, E. B. Cole, A. Pratt, and D. Sartorio, *Glenn L. Martin Co., Baltimore, Md.*

Breakdown problems associated with the operation of antennas at high altitudes and high speeds will be discussed, along with a presentation of some of the proposed solutions to these problems.

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SESSION 15*

TUES. 10:00 A.M.–12:30 P.M.

New York Coliseum Marconi Hall

Information Theory—Review and Recent Advances

Chairman: D. Slepian, *Bell Telephone Labs., Murray Hill, N. J.*

15.1. Cost of Transmission Reliability

R. M. Fano, *Massachusetts Institute of Technology, Cambridge, Mass.*

It has been shown that, contrary to earlier beliefs, the reliability of a communications system disturbed by noise could be made as perfect as desired for a fixed bandwidth, fixed signal power, and fixed transmission range; noise sets inherent limits to the transmission rate at which perfect reliability could be obtained, but not to the degree of the reliability. The cost of greater reliability is paid in terms of terminal equipment complexity and transmission delay. A digital communication system will be used to illustrate the dependence of reliability and its price on the rate of transmission in the channel characteristics. Possible future system development will be discussed, together with some of the theoretical and practical problems that must still be faced in that connection.

15.2. Channel Capacity without Coding

P. Elias, *Elec. Eng. Dept., Massachusetts Institute of Technology, Cambridge, Mass.*

Several communication systems employing feedback are discussed which illustrate an aspect of channel capacity and the trading relationship between the transmission rate, reliability, and delay without involving complicated coding and decoding procedure. These provide simple intuitive interpretations of some of the basic results in information theory.

15.3. Coding a Television Source

J. L. Kelly, Jr., *Bell Telephone Labs., Inc., Murray Hill, N. J.*

The general problem of coding a continuous source for transmission over a discrete channel will be discussed. In particular, examples will be drawn from the field of television. Methods of estimating the rate of a continuous source will be outlined and the results of such estimates compared with known methods of transmission.

* Sponsored by the Professional Group on Information Theory. To be published in Part 2 of the 1957 IRE Convention Record.

15.4. What Good Is Information Theory to Engineers?

J. R. PIERCE, *Bell Telephone Labs., Inc., Murray Hill, N. J.*

Information theory has provided us with a new and precise language in which to talk about communication problems. Sometimes, fortunately, problems in this language give us a clearer understanding of them. It can scarcely be asserted, however, that information theory has led to startling advances in the way we do things.

From a broader point of view, information theory has given us a new way, full of inspiration and confusion, of guiding and evaluating experiments performed on human beings.

SESSION 16*

TUES. 10:00 A.M.–12:30 P.M.

NEW YORK COLISEUM FARADAY HALL

Microwave Tubes

Chairman: V. LEARNED, *Sperry Gyroscope Co., Great Neck, N. Y.*

16.1. The Selection and Applications of Traveling-Wave Tubes

A. H. NIELSEN AND N. W. HANSEN, *Federal Telecommunication Labs., Nutley, N. J.*

This paper studies the traveling-wave tube from the point of the user and describes the procedure in selecting the proper operating performance and circuit design most suited for his application.

The objectives of this paper are twofold: 1) To establish the requirements for the particular application in mind, the evaluation of traveling-wave tube characteristics as a function of this application, and to determine the tube characteristics to be utilized; and 2) to discuss the practical problems associated with designing and packaging a traveling-wave amplifier including power supply circuitry, solenoid design, and cooling.

Equipment will be demonstrated which utilizes the above techniques, showing how a systematic procedure in the selection and packaging of traveling-wave tubes is beneficial.

16.2. X-Band Traveling-Wave Tube Feedback Oscillator

V. G. PRICE, *General Electric Microwave Lab., Palo Alto, Calif.*

The principles of feedback amplifier design have been extended recently to the microwave region to provide stable oscillators capable of being tuned over a wide range. An x-band oscillator is described which utilizes a commercially- available traveling-wave tube amplifier with an external feedback circuit comprised of either a fixed or tunable two-part high-Q cavity resonator. Experimental data on this oscillator are given which indicate the degree of frequency stability achievable on both a short- and long-term basis and, in addition, pushing and pulling information is given for various operating conditions. A comparison is made between the performance of an oscillator of this type constructed of commercially-available components and that of a similar type oscillator constructed with an ultra-stable power supply. Under ordinary laboratory conditions of vibration, ambient temperature, and pressure the first oscillator had a short time stability of one part in 10^6 while the second had a stability of one part in 10^8 (for periods of the order of 20 milliseconds).

16.3. A Light-Weight, Low-Level Traveling-Wave Tube Amplifier for S Band

J. O. BRAMICK, *Federal Telecommunication Labs., Nutley, N. J.*

The electrical and mechanical design of a low-power, all metal traveling-wave amplifier tube will be discussed.

The tube is capable of operating in the frequency range of 2 to 4 kmc at a power level of 100 milliwatts. The minimum gain at rated power output is 25 db. The tube has been miniaturized by locating the rf terminals at opposite ends of the tube, effecting a considerable reduction in the size and weight of both the tube and solenoid. Thus, by a rearranging of the rf terminals, a compact package is achieved in which the maximum diameter of the solenoid is 2 inches, and the combined weight of the solenoid and tube is 2 pounds, 10 ounces.

16.4. The Duplexer as a Means of Eliminating Interference from Nearby High-Power Radar Systems

I. REINGOLD AND J. L. CARTER, *Signal Corps Eng. Labs., Fort Monmouth, N. J.*

The problem of mutual interference between nearby radar systems is becoming increasingly serious. Conventional duplexers are not particularly effective in alleviating the interference problem between systems at the incident power levels in question. An experimental duplexer tube of unique design has been developed and evaluated in an attempt to provide a solution to this interference problem. Preliminary tests to determine performance under interference conditions were most promising.

16.5. A New Method for Modulating Electron Beams for Pulse Applications and Linear Amplitude Modulation Systems

G. M. W. BADGER, *Eitel-McCullough, Inc., San Bruno, Calif.*

The various methods for modulating electron-beam tube devices are discussed. These include linear amplifier service beam voltage modulation and beam current modulation. The advantages and disadvantages of the methods are presented.

One of the ways in which a beam-type electron device can be beam-current modulated is by means of the modulating anode. The anode of a Pierce type gun is electrically isolated from the other elements of the tube so that a modulating potential can be applied. The electrical characteristics of this new modulating element are discussed, together with some of the outstanding construction and fabricating aspects.

The circuits for pulse and amplitude modulation application are covered. The results of considerable experience with various high power klystrons are presented in terms of overall linearity, efficiency phase shift and other experimental performance data.

The modulating anode principle is being applied in other useful areas such as pulse and rectifier tubes. These tubes are analyzed and performance data are presented.

16.6. Behavior of a Backward-Wave Oscillator with External Feedback

F. L. VERNON, JR., *Hughes Aircraft Co., Culver City, Calif.*

An investigation of the effects of deliberately introduced external feedback on the operating characteristics of a backward-wave tube is made. Essentially, two methods are available for predicting these effects. These are discussed and applied to several cases. It is shown that within certain limits a desired tuning curve or a power curve can be synthesized by using the proper frequency characteristic in the feedback line. Using the same methods, it is shown that the effects on the frequency sensitivity with respect to voltage, current, and other external changes can be predicted in terms of external circuit characteristics. This is experimentally and theoretically examined for some practical cases.

SESSION 17*

TUES. 2:30–5:00 P.M.

WALDORF-ASTORIA STARLIGHT ROOF

General Communications Systems

Chairman: R. D. CAMPBELL, *American Telephone and Telegraph Co., New York, N. Y.*

17.1. SSB Modulation for Scatter Propagation

I. H. GERKS AND R. P. DECKER, *Collins Radio Co., Cedar Rapids, Iowa*

There are many instances in scatter propagation in which, because of great path length, limitations on transmitter power, or restrictions on antenna size it is impractical to achieve sufficient signal-to-noise ratio at the receiver for effective use of frequency modulation. An example is the case of air-ground communication. In this case single-sideband modulation is the optimum method for providing at least one voice channel. Certain problems arise, however, when SSB modulation is used on vhf or uhf scatter circuits. Among these are amplifier

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linearity, carrier frequency stability, effective agc action, and diversity combining. This paper considers practical solutions to these problems and describes results secured over a 1070-mile ionospheric scatter circuit at 38.6 mc.

17.2. FM Scatter System Measurements

R. W. Britton and H. D. Hern, *Collins Radio Co., Cedar Rapids, Iowa*

The design of tropospheric scatter communication systems is characterized by the considerations given to the effects of random fading and high propagation loss. To insure equipment performance that is compatible with these stringent design considerations, various comprehensive system measurements must be performed. These measurements are discussed and specific techniques presented with emphasis on diversity combining tests and intermodulation distortion using a random noise loading method. Measured results on one hundred systems is presented in graphical form and compared to the required design values of a typical twenty-four-voice channel system.

17.3. Theory of Feedback Around the Limiter

E. J. Baghdady, *Dept. of Elec. Eng. and Research Lab. of Electronics, Massachusetts Institute of Technology, Cambridge, Mass.*

A new theory for the effect of feedback around the limiter upon interference rejection in fm receivers considers interference resulting from superposition of two carriers differing in amplitude and frequency, and distinguishes between *wide-band* and *narrow-band* feedback. The theory shows that wide-band feedback cannot reduce the magnitude of the frequency spikes caused by the interference regardless of the feedback angle. Inverse narrow-band feedback aggravates the disturbance and raises the limiting threshold. Positive narrow-band feedback, which causes self-oscillation in the absence of input signal, results in pronounced capture improvement and automatic noise squelch, and lowers the limiting threshold.

17.4. General Systems Approaches to Telecommunication Optimization Problems

R. E. Kalaba and M. L. Juncosa, *The RAND Corp., Santa Monica, Calif.*

In the past, for telecommunication networks, it has been difficult to treat analytically system problems of optimal design and utilization. The large number of variables involved in describing the various system capacities, demands of the users, and economic factors have forced investigators to rely on various suboptimization techniques.

By contrast, two recently developed mathematical techniques, *linear programming* and *dynamic programming*, enable one to treat problems—involving perhaps thousands of variables—at the system level in a straightforward and computationally feasible manner. Two telecommunication network extension problems are treated in some detail using these methods. Other applications are indicated.

17.5. The Future Air Force Communication System

C. K. Chappuis, *Rome Air Development Center, Griffiss Air Force Base, N. Y.*

The expansion of air communication requirements has proceeded with fantastic rapidity in the span of the last half century. Most of this expansion has occurred during and since World War II. The end of this expansion in numbers of channels and particularly in capabilities is not in sight. It must increase with higher aircraft and missile speeds, and increased ranges and heights. Also, the advent of space satellites will add to the communication problems The adaptation of the most modern civilian communication system techniques and engineering to Air Force purposes is mandatory as a basic premise. Immediate expansion and improvements to meet the Air Force requirements must follow rapidly.

SESSION 18*

TUES. 2:30–5:00 P.M.

WALDORF-ASTORIA ASTOR GALLERY

Medical Electronics

Chairman: R. L. Butenhoff, *Atomic Energy Commission, Washington, D. C.*

18.1. A Magnetic Tape Recording System for Teaching Electrocardiography

G. N. Webb and W. R. Milnor, *Johns Hopkins Hospital, Baltimore, Md.*

A system for recording ecg and other physiological data in the frequency range of 0.10 to 100 cps on magnetic tape is described. Tests of various grades of tape-handling assemblies, modulation, and demodulating equipment are shown and discussed with respect to the parameters of the ecg desirable for teaching purposes.

Two channels of information are recorded on quarter-inch tape using frequency modulated phantastrons. Playback amplifiers and demodulators are transistorized. Complete circuits of modulators, demodulators, and regulated power supplies are shown. Noise, amplitude, dynamic range, and linearity measurements are illustrated.

18.2. Ultrasonic Dosimetry for Medical Use

V. T. Tomberg, *Biophysical Research Lab., New York, N. Y.*

Ultrasonics are used for medical treatment in physical therapy The margin between harmful doses and not successful doses is very narrow Dosimetry is difficult to apply because of inadequate electronic construction and insufficient knowledge of the overlapping biological effects of heat, mechanical and chemical nature. The physical and technical problems are discussed.

18.3. An Electrical Circuit Analogy for Isotope Kinetics

R. L. Schoenfeld and M. Berman, *Sloan-Kettering Institute, New York, N. Y.*

An electrical circuit analogy is developed to treat the kinetics of isotopic tracers in steady-state physiological systems. The circuit consists of n capacitors connected by nonreciprocal conductances. This structure is analogous to the distribution and steady-state rate of flow of the nonlabeled material. Network functions analogous to driving point and transfer impedances for the electrical circuit are defined from measurements of the kinetics of the traces. Methods carried over from electrical network synthesis permit the formulation of possible models and the mapping of equivalent systems.

18.4. Electronic Control of the Artificial Respiration Cycle

L. H. Montgomery, *Vanderbilt University Medical School, Nashville, Tenn.*

A method of using biological potentials, which are amplified, filtered, and integrated to automatically control the flow of air to and from the iron lung or other type of respirator in accordance with the needs of the patient, is described. Preliminary operational results are discussed.

18.5. The Incorporation of Picture Storage with the Technique of X-Ray Fluoroscopy

W. Gombash, Jr., *Hughes Aircraft Co., Culver City, Calif.*

This paper deals with the application of a half-tone storage tube for the retention of X-ray fluoroscopic images as received from an X-ray phosphor screen. Using this technique it is possible for the viewing radiologist to obtain a brighter more defined image, while at the same time cutting down on the total dosage of X-ray to the patient. This is accomplished by picking up a short exposure, relatively high intensity X-ray fluoroscopic image with a television camera tube, feeding the video signal through a tv chain and displaying and storing the resultant image on a half-tone direct viewing storage tube for subsequent study.

* Sponsored by the Professional Group on Medical Electronics To be published in Part 4 of the 1957 IRE Convention Record.

SESSION 19*

TUES. 2:30–5:00 P.M.

WALDORF-ASTORIA JADE ROOM

New Operational Techniques Concerning Video Test Signals

* Sponsored by the Professional Group on Broadcast Transmission Systems. To be published in Part 7 of the 1957 IRE Convention Record.

Chairman: R. N. HARMON, *Westinghouse Broadcasting Co., Inc., New York, N. Y.*

Panel Members: J. R. POPKIN-CLURMAN AND F. DAVIDOFF, *Telechrome Manufacturing Corp., Amityville, N. Y.*
J. W. WENTWORTH, *Radio Corp. of America, Camden, N. J.*
R. M. MORRIS, *American Broadcasting Co., New York, N. Y.*
W. B. WHALLEY, *Columbia Broadcasting System, New York, N. Y.*
H. C. GRONBERG, *National Broadcasting Co., New York, N. Y.*
J. THORPE, *American Tel. and Tel. Co., New York, N. Y.*
E. W. CHAPIN, *Federal Communications Commission, Laurel, Md.*
A. ST. MARIE, *Canadian Broadcasting Corp., Montreal, Que., Can.*

This panel discussion deals with the subject of video test signals during the vertical blanking interval. This is a new operational technique which permits the transmission of certain video test signals on a continuous basis during normal program transmission. A standardization of test signals for transmission during the vertical interval has not as yet been made by the industry or authorized by the FCC except on an experimental basis. An effort has been made to obtain speakers of authority on this subject. The speakers include representatives from two equipment manufacturers, the three major television networks, The Telephone Long Lines Department, and the FCC. A question and discussion period will follow.

SESSION 20*

TUES. 2:30–5:00 P.M.

WALDORF-ASTORIA SERT ROOM

High Fidelity and Home Measurements

Chairman: F. H. SLAYMAKER, *Stromberg-Carlson Co., Rochester, N. Y.*

20.1. Intermodulation Distortion: Its Measurement and Evaluation

A. PETERSON, *General Radio Co., Cambridge, Mass.*

The unlimited variety of methods of intermodulation distortion measurement are conveniently classified into three major groups according to the number of components in the test signal. At least seven subgroups are sufficiently distinct to merit individual discussion. Since these test methods do not, in general, yield the same information, one or more of them should be selected for each application according to the nature and expected uses of the device under test.

Some recent psychoacoustic investigations are used for judging the significance of the results of intermodulation measurements in terms of audibility of distortion in high-quality reproduction.

20.2. Testing High-Fidelity Amplifiers in the Home

W. W. DEAN, *General Electric Co., Syracuse, N. Y.*

Explicit methods of measurement will be described in order to prevent falling into the pitfalls of false or misleading data. Procedures will be outlined for the measurement of frequency response, power output, equalization, preamplifier overload, sufficiency of gain on the phonograph channels, and residual hum and noise.

20.3. Disk and Magnetic Tape Phonograph Systems

W. H. ERIKSON, *Radio Corp. of America, Camden, N. J.*

Measurement techniques are described with the objective of performance improvement. Major emphasis is on the thorough evaluation of pickup cartridge performance and living room acoustical measurements on loudspeakers. Pickup measurements include optimum vertical force, low and high-frequency tracking capabilities, IM distortion, and frequency response. The most useful test records and tapes are identified and described. The difficulties of living room loudspeaker measurements are outlined and a measurement technique which minimizes these difficulties is described in detail. Methods of improving loudspeaker performance by equalization are discussed and illustrated. Many performance curves of pickups and loudspeakers are shown.

20.4. Improved Low-Frequency Loudspeaker Performance

S. ZUERKER, *General Electric Co., Syracuse, N. Y.*

Present-day home audio systems are usually adequate with respect to frequency response, but improvement of undistorted power output at low frequencies is desirable. The loudspeaker is the weakest element in the system in this respect, although improvements also should be made on power amplifier stability. Analyzing the distorting elements in the loudspeaker and the power requirements, it can be shown that a loudspeaker can be designed to adequately handle all low-frequency power conditions without a significant drop in efficiency, and mounted within an enclosure of smaller than usual dimensions. The gain in maximum power output will be shown in comparison with popular loudspeakers now on the high-fidelity market by means of power response curves.

20.5. A Low-Pressure Phonograph Cartridge

W. E. GLENN, *General Electric Co., Schenectady, N. Y.*

A barium titanate phonograph cartridge is described which is designed to meet tracking requirements below 2 grams tracking pressure. The cartridge has a dynamic mass of only 1/10 of a milligram and is designed so that it has no resonances between 25 cycles and 20,000 cycles. The output after compensation for the RIAA record characteristics is about 40 millivolts. Hum and noise are particularly low with this unit. The vertical and lateral compliance, dynamic mass, protection from damage, simplicity of construction, and other factors are considered in the design. Construction and performance characteristics are given.

20.6. A High-Fidelity Phonograph Reproducer

B. B. BAUER AND L. GUNTER, *Shure Brothers, Inc., Evanston, Ill.*

A new phonograph reproducer is described combining together certain features believed to be essential for high-fidelity reproduction. They are: 1) Practical elimination of friction by use of jewel bearings on all pivots; 2) low arm mass combined with freedom from resonances; 3) damping without interference with the freedom of motion of the arm; 4) tracking error correction; and 5) safe needle lift mechanism to avoid damage to the needle and the record. The cartridge is of moving field type with needle tip mass approaching 1 milligram and is magnetically balanced against hum pickup. The reproducer is capable of tracking conventional records with needle load less than two grams.

SESSION 21*

TUES. 2:30–5:00 P.M.

NEW YORK COLISEUM MORSE HALL

Antennas II—Broadband Antennas

Chairman: A. ALFORD, *Andrew Alford Consulting Engineers, Boston, Mass.*

21.1. High Frequency Steerable Beam Antenna System

E. HUDOCK, *Collins Radio Co., Cedar Rapids, Iowa*

A high-frequency antenna system whose characteristics are those desirable for reliable long-path propagation in the high-frequency range and whose beam is steerable in the azimuth plane is described. High gain at low angles of radiation with patterns containing a minimum of secondary lobes are the chief features of this antenna. The steerable system discussed here is of the Wullenweber type, but of interest is the nature by which two separate and independent arrays are combined in one supporting structure and the wide range of frequencies that each array covers. The lower frequency array is vertically polarized, while that of the higher frequency array is horizontal. Each array has a gain comparable to that of

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a class A rhombic and maintains a satisfactory impedance match (vswr 2:1 and under) over a bandwidth of 2:1.

21.2. Constant Beamwidth Broadband Antennas

C. F. Parker and R. J. Anderson, *Melpar, Inc., Falls Church, Va.*

In a normal horn radiator or aperture type antenna the beamwidth of the main lobe is inversely proportional to the aperture in wavelengths. As frequency is varied the aperture /wavelength ratio varies in direct proportion, providing a one-to-one correspondence between frequency and beamwidth. A new type horn radiator called the "pinwall" antenna has been developed which provides an essentially constant beamwidth over a 4-to-1 band instead of the usual 4-to-1 variation in beamwidth that would result from this frequency change. The basic principle behind the pinwall antenna lies in the replacement of the walls of a horn with pins properly spaced to allow the higher frequencies to radiate from a small aperture while constraining the lower frequencies until larger apertures are reached. End-fire radiators were also investigated and dimensions have been obtained for polyrod antennas which produce a constant beamwidth over a 2-to-1 band.

21.3. Broadband Traveling-Wave Antennas

D. K. Reynolds, *University of Seattle, Seattle, Wash.*

The large class of traveling-wave antennas includes many examples which are superficially quite different, such as the helical antenna, the dielectric antenna, the corrugated surface, and the long Yagi antenna. The essential similarity of these antennas is discussed, and it is shown that the pattern bandwidth is inherently large, and separable from the impedance bandwidth. Broadband methods of excitation are discussed which allow for operation over large frequency ratios. An example is presented of the broadband excitation of a 15 wavelength Yagi antenna.

21.4. Evaluating the Impedance Broadbanding Potential of Antennas

A. Vassiliadis and R. L. Tanner, *Stanford Research Institute, Palo Alto, Calif.*

One of the principal concerns of the aircraft antenna designer is to determine whether an antenna having some known terminal impedance characteristics can be compensated to meet a specified vswr-bandwidth relation. Alternatively the problem may be to select from among possible antenna configurations that one which possesses the greatest impedance broadbanding potential.

In this paper the problem is examined by means of modern circuit theory. Antenna impedances are approximated by rational algebraic fractions and the impedances represented by these functions are treated analytically to determine the vswr-bandwidth relationship which may be obtained by optimum compensation. The functions which can be considered by the techniques developed are sufficiently complex to adequately represent the basic impedance characteristics obtained with typical airborne flush mounted antennas over a frequency range which causes the dimensions of the antenna to vary between a small fraction of a wavelength and approximately a wavelength. Examples are given.

21.5(A). Frequency Independent Antennas

V. H. Rumsey, *University of Illinois, Urbana, Ill.*

Any antenna whose shape is specified entirely by angles obviously is independent of the wavelenth. The infinite biconical antenna is a familiar example There is an infinite variety of such frequency independent shapes but they all extend to infinity. The practical application of this idea therefore depends on how rapidly, if at all, the performance of a finite antenna of this kind converges to the infinite case as the frequency is raised. It appears that the input impedance always converges but that the pattern usually does not converge. There are some striking examples where the pattern does converge, thus giving a practical antenna whose pattern as well as impedance is independent of frequency above a certain frequency. The accompanying paper by DuHamel and Isbell is an example.

21.5(B). Broadband Logarithmically Periodic Antenna Structures

R. H. DuHamel, *Collins Radio Co., Cedar Rapids, Iowa,* and D. E. Isbell, *University of Illinois, Urbana, Ill.*

Antenna structures for which the input impedance and radiation pattern vary periodically with the logarithm of the frequency are described. For a particular class of these structures the variation of the electrical characteristics over a period is negligible, the result being an antenna for which the impedance and pattern are essentially independent of frequency over bandwidths greater than ten to one. The antennas are linearly polarized and bidirectional beams with equal principal plane beamwidths are obtained The beamwidth may be controlled to a considerable extent by the geometry of the structure

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SESSION 22*

TUES. 2:30–5:00 P.M.

NEW YORK COLISEUM MARCONI HALL

Information Theory—Applications

Chairman: M. J. Di Toro, *Polytechnic Research and Development Co., Inc., Brooklyn, N. Y.*

22.1. An Inductive Inference Machine

R. J. Solomonoff, *Technical Research Group, New York, N. Y.*

A study has been made of a category of machines that will perform inductive inferences. A simplified model will be described that only uses a few of a more complete set of heuristic devices. Such a machine is able to learn arithmetic operations from a small set of examples.

By using all of the heuristic devices, it is expected that a machine will be able to learn to perform complex tasks for which it was not specifically designed. Proving theorems, playing good chess, and answering questions in English appear to be within ultimate machine capabilities.

22.2. Multicase Binary Codes for Nonuniform Character Distributions

F. P. Brooks, Jr., *International Business Machines Corp., Poughkeepsie, N. Y.*

For economical transmission, variable-length coding systems are theoretically best for nonuniform character distributions, but difficulties of decoding and checking limit their practical usefulness. A useful class of variable length codes are the multicase codes, in which the characters (messages) to be represented are divided into two or more cases, with shift characters signaling changes in the case of succeeding characters. Analysis of the properties of multicase coding systems yields a method of generating and selecting economical variable-length codes that can be readily encoded, decoded, and checked.

22.3. Binary Transmission Through Noise and Fading

M. Masonson, *Federal Telecommunication Labs., Nutley, N. J.*

This paper deals with the detection of binary modulated carriers, *e.g.* "on-off" radioteletype, fsk, etc., in the presence of noise and fading. Diversification in transmission and reception and "combining" methods are dealt with. System performance is presented in terms of probabilities of error in reception. System capabilities are presented in terms of their (channel) capacities. Various detection (decision) criteria are considered, *e.g.,* minimization of error probability.

22.4. An Estimate of the Degradation in Signal Detection Resulting from the Addition of the Video Voltages from Two Radar Receivers

H. L. McCord, *Hughes Aircraft Co., Culver City, Calif.*

The detection of a pulse radar signal in the video of a radar receiver is treated as a problem in statistics for three cases: 1) a reference case of one radar, 2) a case where the videos of two radars are added linearly, and 3) the case where only the highest video voltage between the two radars at each instant of time is presented to the detection process. The signal-to-noise power ratio required in the IF of the chan-

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nel containing the signal is computed for a probability of detection of 0.50 and a false alarm probability of 1.00×10^{-8}. This signal-to noise power ratio for case 2) and case 3) is compared to that of case 1) the reference case, and estimates of the equivalent degradation in transmitted power result. The estimated degradation for the linearly added case is 2.2 db, while that for the peak selected case. 3). is 0.20 db within the limits of the assumptions used in the analysis.

22.5. The X Carrier: A Telephone Carrier System Employing Bandwidth Compression

J. W. Halina, *Lynch Carrier Systems, Inc., San Francisco, Calif.*

The paper deals with a carrier system for telephone application which employs a method of speech bandwidth compression described as "coherent modulation." Compression is achieved by modulating the speech spectrum with a function of itself.

Both theoretical results and experimental data are reported for prototypes designed for 3-to-1 and 5-to-1 bandwidth compression ratios. The quality of speech transmitted through the system is surprisingly high. Conventional single tone tests for bandwidth and distortion do not detect the presence of a bandwidth compressor in the system and are thus relatively irrelevant as a measure of performance The system exhibits an improvement threshold which is apparently related to a restricted autocorrelation process employed in coherent modulation.

The interesting characteristics of the equipment are economy of parts, simplicity and utilization of conventional circuitry. Development to date has not reached the point of determining the maximum compression ratios realizable.

SESSION 23*

TUES. 2:30–5:00 P.M.

NEW YORK COLISEUM
FARADAY HALL

Televisual Systems Devices

Chairman: S. T. Smith, *Naval Research Lab., Washington, D. C.*

23.1. The Development of 110° Television Picture Tubes Having an Ion Trap Electron Gun

L. E. Swedlund and L. C. Wimpee, *General Electric Co., Syracuse, N. Y.*

The factors leading to the development of 110° deflection angle, television picture tubes are reviewed and in particular the problems of designing an electron gun with an ion trap in the smaller, shorter neck of these tubes, are described. In spite of the smaller space available for the electron gun a design was devised which provides full focused beam current and adequate voltage insulation. Although, because of the restricted space, there appeared to be no simple way to provide for an ion trap the problem was solved by means of a novel off-set grid, ion trap structure which centers the focused beam on the screen without requiring that the electron gun be tilted.

The solution of these problems is illustrated by their application to commercial picture tubes.

23.2. Image Tube Utilizing Bombardment Induced Conductivity

R. W. Decker and R. J. Schneeberger, *Westinghouse Research Labs., Pittsburgh, Pa.*

A television pickup device utilizing a layer of material exhibiting electron bombardment-induced conductivity as the amplifying and storing element is described The device operates in the simplest type of television camera systems. The performance of present experimental tubes indicates ultimate sensitivity comparable to the Image Orthicon It is expected that sensitivity can be increased to the theoretical limits imposed by the efficiency of the photocathode, with resolution adequate for television broadcasting.

23.3. New Developments in the Panel Light Amplifier

B. Kazan, *Radio Corp. of America Labs., Princeton, N. J.*

Using a new electronic system of operation and improved photoconductive materials. an experimental large-area, panel-type, solid-state light amplifier has been developed with light gains of as much as 1000 times. When directly excited by X rays instead of light, such panels produce output pictures 100 times brighter than the conventional fluoroscope screen. The slow decay of the amplifier makes the screen potentially useful for large-screen, bright radar displays. and for the storage of transient images. The nonlinear component materials increase the contrast of the output image, the particular input-output characteristic of the amplifier being determined by the selected mode of operation and the operating frequency.

23.4. An Electrostatic Character-Writing Tube

K. Schlesinger, B. Maggos, and A. F. Hogg, *Motorola, Inc., Chicago, Ill.*

A 19-inch charactron tube has been developed which uses electrostatic fields throughout for character selection and distribution, as well as for image formation and intensification. Two pairs of conjugate electrostatic yokes are used for letter-selection, and a fifth unit for character-positioning at wide angles (70 degrees).

A long decelerating electrostatic lens is used for image formation, permitting instantaneous change of size between small and capital letters.

A new barrier-mask accelerator has been developed to increase beam velocity twelve-to-one over the last inch of its path ahead of the screen.

23.5. A High-Speed, Low Voltage Light Modulator

A. C. Koelsch, *IBM Research Center, Poughkeepsie, N. Y.*

Barium titanate when held above the Curie temperature exhibits double refraction, upon the application of an electric field, that disappears when the field is removed. This Kerr effect is significant in barium titanate for applied fields well below those required for common Kerr cell materials, such as nitrobenzene. This paper will discuss double refraction and the Kerr effect. and in particular, the desirability of operating barium titanate, as an electro-optic light modulator, above the Curie temperature. Experimental results show that light pulses can be attained whose duration are in the low musec region. The effect of mechanical crystal vibrations will be discussed, as well as the light transmission properties of the system.

SESSION 24*

TUES. 8:00–10:30 P.M.

WALDORF-ASTORIA
STARLIGHT ROOF

Applications of Electronics to Air Traffic Control

Chairman: W. R. G. Baker, *Pres., Radio Electronics Television Manufacturers Association*

Moderator: J. L. Anast, *Systems Planning Advisor to E. P. Curtis, Ass't to the President of of the United States for Aviation Facilities Planning*

Panel Members: S. Alexander, *National Bureau of Standards, Washington, D. C.*
C. Wheeler, *Airborne Instruments Lab., Inc., Mineola, N. Y.*
L. Perper, *Tucson, Ariz.*
V. Weihe, *Air Transport Association, Washington, D. C.*
S. Berkowitz, *The Franklin Institute, Philadelphia, Pa.*

A discussion of plans, research, and development on national aviation air traffic control facilities and systems and the use of electronics in the program.

* Sponsored by the Professional Groups on Electron Devices and Broadcast and Television Receivers. To be published in Part 3 of the 1957 IRE Convention Record.

* Sponsored by the Professional Group on Aeronautical and Navigational Electronics and Military Electronics. To be published in Part 8 of the 1957 IRE Convention Record.

SESSION 25*

TUES. 8:00–10:30 P.M.

NEW YORK COLISEUM
FARADAY HALL

Microminiaturization—The Ultimate Technique

Chairman: C. BRUNETTI, *General Mills, Inc., Minneapolis, Minn.*

The cry "make it smaller—make it lighter" has been ringing in the radio-electronics engineer's ears since before World War I and it seems that the more he accomplishes along this line, the louder and more insistent the cry becomes. Much, indeed very much was accomplished in the years between 1918 and 1941 but World War II multiplied the demand for "smaller and lighter" by several orders of magnitude. Actually, in far too many cases the pressure for decreased size and weight was too great and reliability was neglected or even lost sight of. Today, therefore, the modifier " . . . but make it more reliable," has been added to the original cry.

To the modern electronics engineer, this is not at all inconsistent, but is reasonably essential if progress in his chosen field is to continue at its accelerating rate presently observable. He was able very creditably to miniaturize his equipment prior to World War II, to subminiaturize during and after the Korean "police action," but today this is not enough; he must microminiaturize if he's to stay in the running. Some very substantial steps in microminiaturization have taken place and many more are in the offing, sometimes not even recognized as such, just as so many revolutionary developments arrive piecemeal and are not appreciated until someone takes time to review the field and point out the effort that is taking place and, surprisingly perhaps, is intelligently coordinated.

This session, therefore, is to spotlight some of the "microminiaturization" that is now with us or under way and to pose a challenge for engineers in the electronics field to do even better in the future. Can he go beyond "microminiaturization" or is this truly "The Ultimate Technique"? Only time will tell, but from one viewpoint, if an item can be reduced substantially in size and/or weight, then it's still in the miniature or subminiature stage and "Microminiaturization—The Ultimate Technique" is yet to arrive.

25.1. Philosophy of Microminiaturization Technique

C. BRUNETTI, *General Mills, Inc., Minneapolis, Minn.*

The concept of microminiaturization will be introduced and presented in relation to miniature and subminiature techniques. The increasing need for extension of the art of electronic packaging into the smaller regions will be covered. Guide lines, necessary for development and fabrication of useful and practical microminiature electronics, will be described in general terms.

Some new developments in sciences outside the electronic field, which might encourage new ideas or approaches to microminiaturization will be presented.

25.2. The Challenge of the Environment

E. F. CARTER, *Stanford Research Institute, Menlo Park, Calif.*

This talk will show the urgent and basic needs for microminiaturization in order to keep up with the rapid progress in electronic applications, particularly in the mobile field. Much imaginative publicity has been given to the high temperature requirements of equipment for missiles and supersonic aircraft and these will be covered authoritatively but there are other fields such as the infantryman's helmet transceiver that are perhaps equally important where the space requirements cannot even be approached without microminiaturization.

25.3. Material Constituents and Components

H. A. STONE, JR., *Bell Telephone Labs., Murray Hill, N. J.*

This talk will cover as much of the specific field currently available in the way of new materials and techniques. Available components will be shown and discussed and an indication of what further progress may be expected within the next year or so. Needs for additional materials and new types of components not yet available or on the horizon will be stressed as a challenge for the electronics industry to come forward with a practical solution.

25.4. Today's Applications and Equipments

End product uses of microminiature components will be illustrated both by actual equipment and by slides and/or discussion. Speakers will discuss specific fields and items both to show what is now being done and to offer a provocative challenge to others to do even better in the future.

Military

BRIG. GEN. E. R. PETZING (Ret), *Moore School of Elec. Eng., University of Pennsylvania, Philadelphia, Pa.*

Missiles

J. R. MOORE, *North American Aviation Corp., Downey, Calif.*

The guided missile has provided a primary impetus to microminiaturization. This talk will explain how the necessity of replacing human pilots, navigators, and bombardiers with electromechanical counterparts to make guided missiles has forced a concentration on reliability and reduction in size and weight which can only be achieved by microminiaturization. Because missiles used in military action are completely expended, the reduced cost in airframe weight and propulsion equipment afforded by a minimal size and weight of electronic brains and reflexes has an important effect in achieving "more defense per dollar." Added to this is the fact that microminiaturization permits semiautomatic or automatic production techniques which further reduce the cost of missiles by increasing reliability, reducing the cost of electronic elements, and permitting national standardization for mobilization purposes

Methods

W. W. Hamilton, Elgin National Watch Co., Elgin, Ill.

How does one go about "microminiaturization?" Probably the most significant progress in the broad field has been accomplished by the watch industry. This talk covers the application of highly precise watch design and manufacturing methods to frontier electronic technology.

* Sponsored by the Professional Groups on Industrial Electronics, Component Parts, and Production Techniques. To be published in Part 6 of the 1957 IRE CONVENTION RECORD.

SESSION 26*

WED. 10:00 A.M.–12:30 P.M.
WALDORF-ASTORIA
STARLIGHT ROOF

Electronic Computers I—Digital Computers

Chairman: J. P. NASH, *University of Illinois, Urbana, Ill.*

26.1. An RCA High-Performance Tape Transport System

S. BAYBICK AND R. E. MONTIJO, *Radio Corp. of America, Camden, N. J.*

A high-performance, multichannel digital tape transport has been developed to meet the needs of the data processing industry in general. This is a tubeless equipment which provides very fast start and stop times at very high repetition rates through the use of semiconductor and magnetic components.

This paper describes the electronics and mechanism in detail including the methods employed in obtaining start-stop rates to 120 per second, start and stop times of less than 2 milliseconds, and a start-stop spacing of less than 0.2 inches. The transport handles various widths of tape from ½ to 1½ inches and magnetic heads which provide up to 18 recording tracks.

The weight-type reel servo system, the high-current transistor solenoid driver, and the tape control logic are also described. Several unique features of this equipment have been employed in this developmental equipment to achieve performance and enhance its reproducibility.

26.2. A Magnetic Pulse-Current Regulator

J. D. LAWRENCE, JR. AND T. H. BONN, *Remington Rand Univac, Philadelphia, Pa.*

This paper describes a magnetic current regulator using a square hysteresis loop core with two windings. A direct current flowing in one winding holds the core in a saturated condition and provides a current reference for regulation. The core presents a low impedance to a current pulse passing through the other winding until the pulse mmf exceeds the dc mmf. When this happens, the core moves into

* Sponsored by the Professional Group on Electronic Computers. To be published in Part 4 of 1957 IRE CONVENTION RECORD.

the unsaturated region of its hysteresis loop and presents a high impedance to the current pulse, thereby preventing further increase in this current pulse.

Design considerations are presented. The precision of regulation is directly proportional to the number of turns on the pulse winding and inversely proportional to the magnetizing mmf required by the core in its unsaturated region. Hence, precision of regulation is limited by the amount of air core inductance that can be tolerated and the number of turns that it is physically possible to place on a core. The use of a thin-wall metal bobbin substantially improves the regulation.

26.3. Diodeless Magnetic Core Logical Circuits

L. A. Russell, *IBM Research Center, Poughkeepsie, N. Y.*

Magnetic cores having rectangular hysteresis loops have been shown to be useful as a key element in logical circuits for digital computers. However, most of these circuits use diodes for coupling, requiring windings of large numbers of turns, or large cores. A special class of magnetic core logical circuits will be presented in which cores are used for coupling. By avoiding the use of diodes, these circuits offer major advantages in economy, reliability, and compactness in medium speed applications. The basic technique that eliminates the need for diodes requires that some of the cores have a switching threshold. Specific examples of possible circuits and their operating characteristics will be shown.

26.4. Digital Computer Designs Circuit for Longest Mean Time to Failure

J. Alman, P. L. Phipps, and D. L. Wilson, *Remington Rand Univac, Div. of Sperry Rand Corp., St. Paul, Minn.*

This paper describes a system of circuit design utilizing a digital computer. The digital computer is programmed in such a manner so that it can compute the circuit that would give the longest mean time for failure of the circuit. This is accomplished by programming into the computer the characteristics of life test of components. The computer computes the circuit many times looking for the combination of circuit components that would still meet the output requirements and give the longest mean life to failure. The main computer output then becomes just the circuit which would give the longest mean time to failure possible with the existing component characteristics which were programmed into the computer.

26.5. Considerations in the Design of Character Recognition Systems

E. C. Greanias and Y. M. Hill, *International Business Machines Corp., Endicott, N. Y.*

The basic factors pertaining to the Character Sensing problem are discussed. These are range of style, range of quality, and number of characters and symbols to be recognized. Possible definitions of character quality and units for measuring it are described. The information handling steps of the recognition process are outlined as:

1) Conversion of marks on paper to electrical signals.
2) Discrimination between signal and noise.
3) Reduction of filtered data.
4) Identification of characters and symbols based on reduced data.
5) Validity checks.

The use of digital computers in the simulation of data reduction and recognition are described. A method for generating realistic test specimens on a digital computer is outlined.

SESSION 27*

WED. 10:00 A.M.–12:30 P.M.

WALDORF-ASTORIA ASTOR GALLERY

Magnetic Recording

Chairman: M. Camras, *Armour Research Foundation, Chicago, Ill.*

27.1. An Approach to Quantitative Methods for Evaluation of Magnetic Recording System Performance

C. B. Stanley, *Ampex Corp., Redwood City, Calif.*

The selection of an information storage device appropriate to the form and precision of the data analog requires evaluation of the distortions introduced by the system in terms of the critical data parameters.

The effects of nonuniform tape motion, dynamic range, and frequency response upon direct-, fm-, and PWM-recorded data are discussed. Methods are presented for exhibiting system performance specifications in forms suitable for directly selecting the optimum type of translation appropriate to the accuracy and bandwidth requirements of the data

27.2 The Application of Wow and Flutter Compensation Techniques to FM Magnetic Recording Systems

R. L. Peshel, *Ampex Corp., Redwood City, Calif.*

The sources of error present when data signals are recorded and reproduced on magnetic tape by an fm system are identified, and the effect of each type of error on the reproduced intelligence is analyzed.

Several of the methods employed for the compensation of errors arising from unstable tape motion are compared on the basis of effectiveness, complexity, and cost. The problems associated with the design of a compensation system are reviewed.

The relative merits of two commonly used systems are investigated in detail.

27.3. Design of Instrumentation Magnetic Tape Transport Mechanisms

K. Schoebel, *Ampex Corp., Redwood City, Calif.*

The various existing instrumentation tape recorders for use in the field of data reduction are described. The basic design of a new precision magnetic tape transport mechanism is presented in detail from the development of a prototype to the full production. It is demonstrated how mechanical design can reduce wow and flutter to an extremely low value and in many cases eliminate the need of electronic compensation. A complete description of the tape transport mechanism is presented—size, capability, and performance. Modifications of the standard tape transport, such as a 120 inches/sec search-drive, a multispeed drive system, and others are described.

27.4. The Reverbetron

P. C. Goldmark and J. M. Hollywood, *CBS Labs., New York, N. Y.*

A magnetic tape reverbetron is described. This device for producing synthetic reverberation has been developed into models suitable for studio or home use. A brief historical outline of the course of development is given.

The subjective effects of reverberation time, percentage of reverberation, and echo repetition rate are discussed. The choice of range for these parameters is given. Design considerations are discussed. A block diagram and schematic are shown, and pictures of studio and home models. A demonstration of the reverbetron unit is given.

Comparison is made with a typical echo chamber by showing comparative frequency response and oscillograms of transient response.

27.5. A Multichannel Transducer for Magnetic Recording

H. A. Johnson, *Shure Brothers, Inc., Evanston, Ill.*

This paper describes an unique method of construction for a magnetic transducer element for magnetic recording and reproducing equipment and a stacking means whereby a plurality of elements can be utilized for multichannel applications. Where two or more elements are juxtaposed, such as in stereophonic recording and similar applications, crosstalk considerations become rather significant. In order to arrive at satisfactory crosstalk figures it is necessary to consider two sets of conditions: 1) when only one channel is being recorded at a particular time, and 2) when several channels are being recorded simultaneously. The results obtained from the crosstalk measurements, along with the frequency response characteristic and operating parameters for the elements, are presented.

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* Sponsored by the Professional Group on Audio. To be published in Part 7 of the 1957 IRE Convention Record.

SESSION 28*

WED. 10:00 A.M.–12:30 P.M.

WALDORF-ASTORIA JADE ROOM

Nuclear Instrumentation

Chairman: M. A. SCHULTZ, *Westinghouse Commercial Atomic Power, Pittsburgh, Pa.*

28.1. Track Recognition System for Scanning Nuclear Emulsions

S. BECKER AND J. FRANCESCHINI, *Airborne Instruments Lab., Inc., Mineola, N. Y.*

An experimental scanner using television techniques has been built to detect and count neutron tracks in the photographic emulsion used in monitoring personnel radiation exposure. The principal problem is the reading of very short tracks in a background of artifacts and random grains.

Artifacts or grain clusters with low aspect ratio are rejected by a form of cancellation similar to that used to eliminate radar ground clutter. The duration and continuity of the canceller output signal is then screened to pass signals characteristic of straight tracks with close grain spacing.

Statistics for the automatic scanner are given and compared with those for existing manual techniques. The maximum practical scanning rate is estimated.

28.2. Multichannel Analyzer for Time-of-Flight Experiments

H. L. GARNER AND R. E. MILLER, *University of Michigan, Ann Arbor, Mich.* AND S. H. MCMILLAN AND R. R. GRAHAM, *Strand Engineering Co., Ann Arbor, Mich.*

The work described in this paper was carried out as one portion of a program by the Knolls Atomic Power Laboratory, Yale University, and Columbia University for the Atomic Energy Commission. This program required the development of instrumentation for the collection of data on the velocity distribution of neutrons. This instrumentation was to provide a considerably higher resolution and capacity than previously obtainable.

A cathode-ray tube monitor permits visual examination of the accumulated count of selected groups of channels while the experiment is in progress.

The output unit operates a standard commercial card punch which permits analysis by general purpose computers.

28.3. 0.1-Microsecond, 2000-Channel, Electrostatic Storage System for Time-of-Flight Experiments

J. HAHN, *Dept. of Physics, Columbia University, New York, N. Y.*

An instrument has been developed for measuring neutron time-of-flight which has 2000 discrete time channels, each having a width of 0.1 microsecond. A temporary electrostatic storage is used in conjunction with a magnetic drum memory. Neutrons initiated by a cyclotron burst, which occurs at approximately a 60-cps rate, are detected after traversing a fixed flight path, and their times of arrival are stored in the electrostatic memory. Before the next burst occurs the stored information is read into the drum, and the storage tube is cleared. This paper describes the electrostatic storage system and circuitry. The major system blocks which are discussed are: the 10-mc pulsed oscillator and clock pulse generator; the "clock-stopper" or staticizer; the fast carry flip-flop deflection circuit drivers: the current adder stairstep deflection generators, and the storage tube.

28.4. New Double-Line Linear Amplifier

G. G. KELLEY, *Oak Ridge National Lab., Oak Ridge, Tenn.*

A new amplifier has been developed for scintillation spectrometry; it has overload characteristics suitable for use with very large detectors. This amplifier, called the A-8, recovers from a 4000-times overload signal in about 8 μsec. There is no positive base line excursion after the main pulse. It uses the double delay line differentiation principle, has a gain of 13,500 in the main amplifier, and an extra factor of 1, 3, or 10 in the preamplifier. The gain control range is by factors of 2 over a total range of 64. Rise time is about 0.18 μsec. The output stage is capable of driving a 1000-ohm load to greater than 100 volts in both directions. The power requirement is about the same as for an A-1 amplifier.

28.5. Radioisotope Thermoelectric Generator

J. L. BRIGGS, *Rome Air Development Center, Griffiss Air Force Base, N. Y.*

Recent advances in the field of solid-state physics have greatly enhanced the possibility of developing a practical thermoelectric generator for power supply electronic equipments. The possibility of utilizing an efficient thermopile driven by decay energy derived from isotopes is suggested. The course of development of this device at RADC will encompass three problem areas: 1) geometry and packaging of radioisotope thermal source; 2) development of efficient thermopile, and 3) consideration of circuits best suited to this type of power supply.

* Sponsored by the Professional Group on Nuclear Science. To be published in Part 9 of the 1957 IRE CONVENTION RECORD.

SESSION 29*

WED. 10:00 A.M.–12:30 P.M.

WALDORF-ASTORIA SERT ROOM

Circuit Theory I—Symposium on Modern Methods in Network Theory

Chairman: S. DARLINGTON, *Bell Telephone Labs., Murray Hill, N. J.*

The first half of the Symposium consists of three invited papers, each concerned with one of three branches of network theory in which much work is currently being done. These papers by recognized experts in the field will attempt to survey the present state of the art in each area and lead into some of the problems under investigation at present.

The second half will be a panel discussion in which the three previous speakers will be joined by B. J. Dasher (Georgia Inst. Tech.), M. S. Corrington (RCA, Camden), E. S. Kuh (Univ. of California), A. D. Fialkow (Brooklyn Polytech. Inst.), and H. J. Carlin (Brooklyn Polytech. Inst.). The panel will discuss some of the current problems in network theory, the progress being made in them, and the need for future studies.

29.1. Synthesis Techniques and Active Networks

J. G. LINVILL, *Stanford University, Stanford, Calif.*

Synthesis theory for passive networks, as an aid in conception, neatly separates the possible from the impossible; as a practical technique of network design the theory is useful since paper designs lead to good laboratory designs. With respect to active networks the same two parallel aspects, theoretical implications and practical techniques, emerge but assume different importance.

The realm of theoretical possibilities is expanded when an active element in the form of an ideal amplifier, a negative resistance, or a negative impedance converter is introduced. With the introduction of active elements one can eliminate one kind of reactance without loss of generality, can compensate for incidental lossiness in reactors, and can incorporate power amplification into the network.

Practical considerations introduce a new dimension into active network design. This new dimension arises through the fact that characteristics of active elements are more inclined to drift with time and environment than passive elements. The designer must evaluate sensitivity of performance to changes in active elements and design structures which are maximally tolerant of variations in elements. Some preliminary guides can be given but many interesting problems are yet to be solved.

29.2. The Frequency-Time Representation of Signals Using Natural Components

W. H. HUGGINS, *The Johns Hopkins University, Baltimore, Md.*

A wide class of signal representations are characterized by a resolution into components $k(t;\lambda)$ involving a single parameter λ, according to the form

$$u(t) = \sum_{\lambda} k(t;\lambda)U(\lambda)$$

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where $U(\lambda)$ is the signal spectrum as a function of λ. For representation in the "frequency domain," $k(t;\lambda)=\exp(\lambda t)$ for $t>0$, all components have the *same epoch* at $t=0$, and each component has a *different waveform* that depends upon the "frequency" parameter λ. On the other hand, for "time-domain" representation used in sampled-data systems, $k(t;\lambda)=\Delta(t-\lambda)$, where Δ is some interpolating function such as the cardinal function, all components have the *same waveform* $\Delta(\tau)$ and each component has a *different epoch* that depends upon the sampling instant λ.

Since a "frequency" representation always implies at least one epoch, and a "time" representation always implies at least one component waveform, "frequency" and "time" are inseparable attributes of a signal representation. A more general, and often simpler and more meaningful, representation involving multiple frequencies and multiple epochs may be written as

$$u(t)=\sum_{j,k} A_{j,k} f_j(t-t_k)$$

where $f_j(\tau)=\exp(\lambda_j\tau)$ are damped natural exponential components that vanish for $\tau<0$. Because these components decay to zero with the passage of time they permit a concise and physically meaningful definition of a time-varying spectrum. The problem of approximating a given signal with an expression of this sort is discussed and the design of a signal analyzer capable of measuring the parameters $\{A_{j,k}\}$ is described.

29.3. Signal Flow Graph and How to Avoid Them

S. J. Mason, *Massachusetts Institute of Technology, Cambridge, Mass.*

Signal flow graph topology and network topology are both useful in linear electronic circuit analysis. Flow graphs lend themselves most easily to circuits principally composed of unilateral elements whereas classical network-topological methods are applicable to circuits containing only reciprocal elements. By a very simple modification the classical topological rules for reciprocal branch network analysis can be adapted to circuits containing nonreciprocal elements, thereby permitting electronic circuit models to be analyzed by inspection and without flow graphs.

SESSION 30*

WED. 10:00 A.M.–12:00 NOON

WALDORF-ASTORIA GRAND BALLROOM

Engineering Management Technique

Chairman: H. N. Skifter, *Airborne Instruments Lab., Inc., Mineola, N. Y.*

30.1. The Art of Selection of Engineering Management Talent

C. W. Randle, *Booz, Allen, and Hamilton, Chicago, Ill.*

The growth and increasing importance of engineering, in combination with the shortage of engineers and the general shortage of management talent, have increased the desirability of defining engineering management selection standards and measuring engineers against these standards. The characteristics of the engineer vs the characteristics of the manager will be discussed and their differences, as well as their common characteristics, will be brought out.

30.2. The Art of Human Relations: Manipulation or Motivation?

A. Levenstein, *Research Institute of America, New York, N. Y.*

The shortage of personnel calls for action, even where there is no prospect of increasing the number of people available. The answer may very well be *not* more people, but better people at work. Under present circumstances, human relations in industry become critical, more important than ever. Unfortunately, this relatively new approach to urgent problems is being seriously weakened by those who believe that manipulative devices can be effective. They can't. Better human performance depends on 1) developing new management attitudes, 2) working out means of communicating those attitudes, and 3) initiating programs of motivation that genuinely identify the areas of mutual interest for all involved in the production process.

30.3. The Art of Delegation of Authority

W. J. E. Crissy, *Personnel Development, Inc., New York, N. Y.*

It is axiomatic in management theory and practice that: 1) responsibility inheres in the individual; 2) responsibility cannot be shared; 3) responsibility cannot be delegated, and 4) authority must be commensurate with responsibility if objectives are to be reached. In your business or mine, this means that the head of the company is fundamentally responsible, for better or worse, in all matters, yet obviously the head of a business cannot do everything himself. If he could there would be no need for other people.

An examination of these axioms from the psychological standpoint leads us to many ramifications which *in toto* reflect themselves in the "climate" that exists within the business and the reputation it has in the eyes of its various publics. Specifically, let us examine the dynamics of delegation from the standpoint first of the delegator, and second, the delegate. This separation you will recognize as arbitrary since every executive at whatever level, except the top, holds these two roles simultaneously.

The job assignment of every executive calls for planning, seeing, doing, and measuring activities. At the top echelons of management, the demands are mostly for planning and measuring. In the middle echelons, the demands are mostly for seeing and measuring and at the first level of supervision for seeing, doing, and measuring. Delegation is tied most intimately to seeing or supervising activities though, of course, antecedent planning activity must take place.

Now let us examine why proper delegation is difficult to achieve. First, not all executives have the temperamental make-up needed for delegation. For example, executive insecurity begets a desire to know exactly what every delegate is doing. Then too, executives sometimes view themselves as indispensable—"the whole show." This prevents them from allowing those working for them to be recognized. Second, the intellectual make-up of the individual may make delegation difficult. He may not honestly see the need for extending authority down the line. He may see himself as the "expert knower." Third, lack of requisite communications skill may prevent the executive from delegating. He knows how to do the job himself but cannot communicate what to do and how to do it to others.

Similarly, viewing this from the delegate's standpoint, some people are loath to assume responsibility and find it more secure to clear decisions up the line. Also delegates may not fully understand what is expected and yet are loath to reveal their ignorance. Finally, it is often difficult to straighten out communications on complex assignments and the delegator has one view but the delegate has a discrepant one.

The management ideal should be that everyone at every level have commensurate authority to carry out his responsibilities.

SESSION 31*

WED. 10:00 A.M.–12:30 P.M.

NEW YORK COLISEUM MORSE HALL

Transistor Applications

Chairman: L. R. Fink, *General Electric Co., Schenectady, N. Y.*

31.1 Circuit Considerations for High-Frequency Amplifiers Using Drift Transistors

J. W. Englund and A. L. Kestenbaum, *Radio Corp. of America, Somerville, N. J.*

This paper describes design considerations for high-frequency circuits using new drift transistors in which the useful frequency response has been increased by an order of magnitude over conventional junction transistors without changing the configuration of the alloy structure. Circuits are presented showing the use of these transistors in a two-stage unneutralized 455-kc amplifier, a neutralized single-stage IF amplifier, a two-stage IF amplifier operating at 10.7 mc for fm receivers, and a three-band portable radio receiver covering the broadcast band (540 to 1630 kc) and short-wave bands (4.75 to 11 mc and 10 to 23 mc). In the portable receiver, the drift transistors are used as an rf amplifier a mixer, and a separate oscillator. The electrical characteristics of the drift transistors are defined and performance curves illustrating their performance at high frequencies are presented.

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* Sponsored by the Professional Group on Broadcast and Television Receivers. To be published in Part 3 of the 1957 IRE Convention Record.

31.2. Design Considerations in the First Stage of Transistor Receivers

L. A. Freedman, *RCA Labs., Princeton, N. J.*

This paper includes a discussion of noise performance of transistor rf stages utilizing capacitive antennas and of transistor mixer stages utilizing loop antennas. Examples of the noise performance to be expected with each type of antenna are included. Comparisons are drawn between transistor stages and corresponding tube stages. Consideration is given to design compromises between image rejection and insertion loss for an rf stage employing both tuned input and interstage transformers. The procedure for transformer design for optimum insertion loss-image rejection performance is outlined.

31.3. A Six-Transistor Portable Receiver Employing a Complementary Symmetry Audio Output Stage

D. D. Holmes, *RCA Labs., Princeton, N. J.*

A complementary symmetry audio output stage offers advantages of simplicity and of economy of components over a conventional transformer-coupled arrangement. When applied to a broadcast receiver, the elimination of audio transformers can be instrumental in providing a striking subjective improvement in receiver audio quality. This paper discusses the unique problems which arise with respect to the integration of a complementary symmetry circuit in a complete receiver design. A six-transistor receiver is described featuring novel audio, volume control, and agc circuitry which makes practicable the exploitation of the inherent advantages of complementary symmetry.

31.4. Transistor Receiver Circuits

A. Proudfit, K. M. St. John, C. R. Wilhelmsen and R. J. Farber, *Hazeltine Corp., Great Neck, N. Y.*

A considerable portion of the cost of a transistor broadcast receiver is represented by the transistors themselves. This paper describes the use of multiple unit grown junction germanium transistors in a manner that effects a significant cost saving in the complete receiver.

The bulk of the cost reduction is due to a lower price for the transistors used. Departures from conventional circuits are necessary to take advantage of the new transistors. A number of these new circuits are described along with a typical receiver. Performance data for the receiver indicate that there has been no compromise in performance with these new techniques.

31.5. Transistor Circuit Problems in TV Receiver Design

E. M. Creamer, Jr., L. H. DeZube, J. P. McCallister, *Philco Corp., Philadelphia, Pa.*

The paper discusses the technical problems that arise in designing transistor circuits to perform several television receiver functions. The economic factors are treated in terms of the minimum number of transistors and components required per set function. The technique employed is to consider the basic requirements of the sound and picture transducers and to specify circuits and transistors which will meet these needs. Vacuum tube experience is adapted where useful, although the special properties of the transistor often permit advantageous designs not previously possible. Examples are given of circuits which so far have been investigated. These circuits are generally suitable for use in combination with other circuits employing vacuum tubes.

SESSION 32*

WED. 10:00 A.M.–12:30 P.M.

NEW YORK COLISEUM MARCONI HALL

Microwave Antennas

Chairman: D. D. King, *Electrical Communications, Inc., Baltimore, Md.*

32.1. A Versatile Multiport Biconical Antenna

R. C. Honey and E. M. T. Jones, *Stanford Research Institute, Menlo Park, Calif.*

This paper describes a versatile, multiport, biconical antenna that can be used as a wide-band direction finder or multiplexer. When the antenna is used for reception, incident plane waves excite in the feeding coaxial line both the TEM mode and the orthogonal TE_{11} mode whose azimuthal orientation depends on the direction of arrival of the signal. Directional information can be obtained by measuring the sum of these two modes at four fixed detectors arranged at 90° intervals around the coaxial line. Alternatively the linearly polarized TE_{11} mode can be resolved, with appropriate circuitry, into right- and left-hand circularly polarized TE_{11} modes. Then directional information can be obtained by measuring the phase difference between either of the circularly polarized modes and the TEM mode. This latter form of direction finder is well suited to multiplexing applications because each of its three ports is well isolated from the others. Furthermore, this antenna has the unique property that a signal fed into any one of these three ports will cause the antenna to radiate omnidirectionally in azimuth. A waveguide version of this antenna has been built and tested and found to operate well over the frequency range of 8.2 to 12.4 kmc.

32.2. Recent Annular Slot Array Experiments

K. C. Kelly, *Hughes Aircraft Co., Culver City, Calif.*

Experimental results on several *X*-band designs for annular slot planar arrays are presented. Three types were considered. The first generates a pencil beam perpendicular to the plane of the array and was undertaken to explore the possibility of producing beams of this type without resort to structures consisting of a multiplicity of rectangular waveguides. The second type produced beacon patterns of various shapes in elevation. These beacon antennas were used independently or to excite a slow wave surface antenna. The third type of design produced a pencil beam in or near the plane of the array. Scanning in azimuth was possible by a small motion of the feed point in the radial transmission line which excites the slots.

Slot coupling data pertinent to obtaining specified aperture distributions are presented.

32.3. Radiation from Modulated Surface-Wave Structures—I

F. J. Zucker, *Air Force Cambridge Research Center, Bedford, Mass.*, and A. S. Thomas, *A. S. Thomas, Inc., Boston, Mass.*

A "modulated" surface wave is one whose phase and/or amplitude varies periodically as the wave propagates along the surface. Structures that support such a wave are characterized by an effective index of refraction that varies in the direction of propagation; for example, Simon's "Cigar" antenna (which inspired this work), or a Yagi with variable element spacing or a variable thickness dielectric slab.

Pattern calculations based on harmonic analysis of the spatial frequencies contained in phase-and/or-amplitude-modulated waves show that surface wave antennas can be built 1) with very high end fire gain or 2) with the beam tilted at an arbitrary angle with the surface (including broadside) Preliminary experimental evidence will be presented.

32.4. Radiation from Modulated Surface-Wave Structures—II

R. L. Pease, *Hughes Aircraft Co., Culver City, Calif.*

Approximate expressions are derived for the electromagnetic fields in a surface wave which propagates along a typical modulated structure—a rectangular slab of uniform thickness, mounted on a perfectly conducting surface, whose dielectric constant and/or permeability vary slowly in a sinusoidal manner along the direction of propagation. Radiation patterns are computed for such a structure of finite length set in an infinite ground plane. In contrast to the endfire pattern obtained from a homogeneous slab, it is possible to obtain a tilted beam from the modulated structure by proper control of the amplitude, wavelength, and phase of the structure modulation.

32.5. The "Sandwich Wire" Antenna: A New Microwave Line Source Radiator

W. Rotman and N. V. Karas, *Air Force Cambridge Research Center, Bedford, Mass.*

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* Sponsored by the Professional Groups on Microwave Theory and Techniques and Antennas and Propagation. To be published in Part 1 of the 1957 IRE Convention Record.

A new microwave line source configuration is described. Basically, it consists of three continuous co-planar conductors; the outer conductors which are parallel to one another are at ground potential while the center conductor which is excited is bent in a sinusoidal manner with a period (for broadside radiation) equal to the wavelength. The polarization is transverse to the length of the array.

Modifications of the basic design include a printed circuit (metal on dielectric) two-dimensional array which is fed by a corporate structure feed, a helical structure which has an omnidirectional pattern and a circularly polarized linear array. Advantages of this construction are mechanical simplicity, good impedance characteristics, and good control over the aperture illumination.

32.6. Recent Developments in the Study of Printed Antennas

J. A. McDonough and R. G. Malech, *Airborne Instruments Laboratory, Inc., Mineola, N. Y.*

Some interesting developments have occurred recently in the field of printed antennas. It is now possible to accurately print end-fire arrays, whereas reference 1 discusses only broadside arrays. A procedure has been developed which permits accurate scaling of lower frequency Yagi arrays to high frequency (microwave) printed Yagis. The exact expressions for the gain function of a rhombic over a semi-infinite perfectly conducting ground plane have been developed. Using these equations, a rhombic was designed and printed. The performance of this rhombic closely correlated predescribed specifications. Two such rhombics have been conductively arrayed with successful results. Some investigation has been done with printing parasitic rhombics to attain illumination control. Slightly narrower beamwidth and lower side lobes have been recorded. An elliptical configuration has been printed and tested. The performance of the ellipse compares favorably with the performance of the rhombic.

Printed "ladder type" end-fire arrays have been fabricated at *L*, *S*, *C*, and *X* band. These antennas are of the surface wave type and have been made to operate successfully up to 16 wavelengths long at *S* band. Illumination is controlled by modulating the element lengths or the distance between elements.

Broadside arrays have been designed and abricated which employ capacitive coupling techniques. Short, wide dipoles are closely spaced to provide a phase reversal at the capacitive gap. Illumination probe measurements have been made and the data obtained have been correlated with the radiation pattern.

SESSION 33*

WED. 10:00 A.M.–12:30 P.M.

NEW YORK COLISEUM
FARADAY HALL

Electron Tubes—General

Chairman: G. M. Rose, Jr., *Radio Corp. of America, Harrison, N. J.*

* Sponsored by the Professional Group on Electron Devices. To be published in Part 3 of the 1957 IRE Convention Record.

33.1. Practical Design Theory for Minimization of Vibration Noise in Grid-Controlled Vacuum Tubes

G. Gross, *Raytheon Manufacturing Co., Newton, Mass.*

Theory shows vibration noise minimization is achievable through electrical and/or mechanical design. It is shown, however, that determination of requisite conditions by operations on the plate current equation is invalidated in the island effect region, commonly the region of receiving tube design. This results from a substitution into the plate current equation of geometric functions defining the electrical parameter μ which are themselves inapplicable in this region.

The practical design theory presented here is based upon empirical determination of the μ function and consequent application of its variance with vibration to either: 1) reduce its vibration effect to zero, or 2) use it to cancel other vibration effects.

Successful application of the theory is illustrated in the design of the CK 6533, a subminiature triode with extremely low vibration output. Similar application to pentodes is indicated.

33.2. Electrolytic Tank Measurements of Mesh Grid Characteristics

H. Hsu, *General Electric Co., Syracuse, N. Y.*, and C. E. Horton, *General Electric Co., Owensboro, Ky.*

Mesh grids are finding increased use in such devices as storage tubes, camera tubes, and receiving tubes; but unfortunately most of the available design equations apply only to parallel wire grids with circular wires. A convenient electrolytic tank is described in which the electrostatic fields associated with mesh grids were duplicated. This arrangement permits many of the dimensions of the configurations to be continuously variable. Grid wires of both circular and rectangular cross section were studied in parallel wire grids and in mesh grids with both square and rectangular openings. The method also permits measurements of triangular and hexagonal configurations.

33.3. Rare-Earth Oxide Cathodes

L. J. Cronin and J. H. Apelbaum, *Raytheon Manufacturing Co., Waltham, Mass.*

In the field of physical electronics, there is need for electron emitting materials which will compete or improve on existing designs utilizing thorium dioxide. With this in mind, investigations were conducted on the following rare-earth materials—gadolinium oxide, neodymium oxide, samarium oxide lanthanum oxide, didymium oxide, and combinations of these and other oxides. Measurements on these materials for thermionic emission data were taken in simple diodes with the emitting material held in a molybdenum mesh. Processing of the materials and of the vacuum diodes are described. Values are given of the dc and pulse emission data. These data are reported as a function of life and in comparison with a standard 100 per cent thoria cathode. The results indicate this class of materials offers definite possibilities as useful cathode materials.

33.4. Temperature Distribution in Anode Structure for Pulse Input

R. N. Ghose, *The Ramo-Wooldridge Corp., Los Angeles, Calif.*

Heat flow equation for the anode structure of a water cooled high power transmitting tube has been solved in cylindrical coordinates subject to boundary conditions which require a constant temperature at the inner surface of the anode and a pulse type of anode current. The temperature distribution in the entire region of the anode structure is expressed, in this paper, both as a function of time and the geometry of the anode. Comparison of temperature distribution at the anode structure is also made for the pulse and sinousoidal types of anode currents. The analysis presented in the paper can be generalized for any anode current distribution.

33.5. A Positive Grid Voltage-Space Current Division Test for Power Vacuum Tubes

J. A. Jolly, *Eitel McCullough Inc., San Bruno, Calif.*

A new positive grid voltage-space current division test for power vacuum tubes is presented. The existing test techniques for power vacuum tubes and their limitations in the positive grid voltage-high space current region are indicated. The new test is covered by discussion and data presentation that indicate the ability to measure tube-to-tube electrical variations in the positive grid voltage region. Related mechanical tube variations and dynamic circuit effects for one tube type are illustrated.

A particular application of the positive grid voltage test as related to the evaluation of oxide cathodes is included.

33.6. Electron Tubes for Critical Environments

W. H. Kohl, *Stanford Research Institute, Menlo Park, Calif., and Stanford University, Stanford, Calif.*

The rapid advances in the technology of weapons systems, and also in specialized applications for civilian use, are putting ever increasing demands on the reliability of electron tubes operating in critical environments. During the past year, Stanford Research Institute has been under contract with Wright Air Development Center to survey the present state of the art of tube-making for applications where envelope temperatures up to 500°C, high vibration and shock levels, and high neutron radiation flux densities are encountered. This paper will summarize our findings on the basis of a survey of the literature, and of numerous interviews with people in research and industry.

SESSION 34*

WED. 2:30–5:00 P.M.

WALDORF-ASTORIA STARLIGHT ROOF

Symposium—Long Range Telemetry and Remote Control

Chairman: M. V. Kiebert, Jr., *The Miami Shipbuilding Corp., Miami, Fla.*

34.1. Electronic Control and Instrumentation of Extra-Atmosphere Space Craft

M. V. Kiebert, Jr., *The Miami Shipbuilding Corp., Miami, Fla.*

The advent of space flight, initially in unmanned craft and ultimately in manned craft, poses new problems in telemetry and radio control techniques which must be considered at this time. A "holding pattern" of perhaps 60,000 miles or more, a fuel and oxidizer consumption of tons per minute, combined with a reentry problem necessitating expenditure or dissipation of large amounts of energy, will require early adoption of a "common" system of macroscopic capabilities that will dwarf the air navigation and control problems that now confront the aviation industry in the transition from piston to jet aircraft. The presently visualized problems, including propagation phenomena, environmental considerations, flight path, and/or trajectory control will be outlined and compared with the author's previously published paper "Electronic Control and Instrumentation of Aircraft," which was presented at the joint R.Ae.S.I.A.S. meeting in London in 1947.

34.2. Progress in Telemetering of Data from High Velocity Missiles in Upper Atmosphere

R. J. Burke, *Lockheed Corp., Palo Alto, Calif.*

In order to collect data concerning the reentry of bodies into the earth's atmosphere, Lockhead Missile Systems Division has been carrying on an extensive program for the Air Force using a multistage rocket. This vehicle is designed to leave the atmosphere powered by its first stage and then to turn over and reenter at very high speeds attained by the thrust of its second and third stages. A large amount of information has already been obtained by telemetering from these vehicles and although much of it is still classified, some indication can be given of the problems encountered, and in particular a description will be given of a peculiar phenomenon observed in the variation of radio frequency field strengths under these flight conditions.

34.3. Long Range Telemetering Reception

J. B. Wynn, *RCA Missile Test Center, Melbourne, Fla.*

Reception problems concerned with long range telemetering will be discussed. Consideration will be given to signals arriving at low elevation angles, originating from vehicles at considerable slant ranges, but reasonable altitudes.

This paper will be based on unclassified experience obtained in the operating area included in the Air Force Missile Test Center.

34.4. Some Dynamic Aspects of Control at Long Ranges

D. T. Sigley, *Firestone Tire and Rubber Co., Los Angeles, Calif.*

The problem of instrumenting space craft from the point of view of the control problem will be discussed. Questions of shading, angular velocities, accelerations, and accuracies of measurement and control will be discussed.

34.5. Problem in Measuring the Space Environment of the Earth

A. J. Max, *Sandia Corp., Albuquerque, N. M.*

This paper will discuss instrumentation and telemetering for space craft to measure physical data, such as magnetic radiation, solar radiation, gamma radiation, sunspot activity, etc. It will include a discussion on environmental problems, such as shock and acceleration encountered by this instrumentation.

34.6. A Microwave Telemetry Relay

K. A. Hall, B. J. Lamberty, and L. S. Taylor, *Flight Determination Lab., White Sands Proving Ground, N. M.*

A 2200-mcps multichannel telemetry relay system has been developed at White Sands Proving Ground. This equipment is designed to provide a high capacity net interlinking all data-recording sites and the fixed and mobile receiving stations on the proving ground. In addition, simultaneous calibration of all stations is possible. The relay employs the superheterodyne principle to translate all the vhf telemetry signals as a unit to the microwave region for transmission to the recording stations. The system features a large dynamic range. Close channel spacing is utilized for efficient use of bandwidth. Unattended operation of the equipment is possible.

* Sponsored by the Professional Group on Telemetry and Remote Control. To be published in Part 5 of the 1957 IRE Convention Record.

SESSION 35*

WED. 2:30–5:00 P.M.

WALDORF-ASTORIA ASTOR GALLERY

Speech Analysis and Audio Amplifiers

Chairman: H. F. Olson, *Radio Corp. of America Labs., Princeton, N. J.*

35.1. A Demonstration of the Representation of Speech by Poles and Zeros

S. H. Chang and R. Bach, Jr., *Northeastern University, Boston, Mass.*

Aside from the phonemic description of speech the most effective representation of speech is supplied by the dynamic model. The latter concept of excitation functions and system functions is very appealing to communication scientists. Work remains to be done to demonstrate how successful this concept is in solving speech compression problems. This paper demonstrates our progress to date.

35.2. A High Efficiency Speech Amplifier

H. Sullivan, *David Bogen Co., Inc., New York, N. Y.*, and J. Nelson, *Flushing, N. Y.*

A 500-watt audio amplifier for speech use operating at an over-all efficiency of 80 per cent is described. The plate efficiency of the output stage is approximately 98 per cent. These high efficiencies are achieved by using infinitely clipped speech so that the output consists of rectangular pulses and the output tubes operate as switches. The method of rating tubes for this service, the efficiencies to be expected, and the precautions to be taken to assure high articulation, are discussed. Word articulation scores using the PB50 word list exceed 90 per cent.

35.3. 50 Watt High Quality Transistor Audio Power Amplifier

A. B. Bereskin, *University of Cincinnati, and The Baldwin Piano Co., Cincinnati, Ohio*

A transistor audio power amplifier capable of delivering power in excess of 50 watts has been developed. The power delivering capacity of this amplifier is down less than 3 db at 20 and 15,000 cycles while the low level frequency response is down 3 db at about 60 kc. The desirable operating characteristics have been achieved by strict Class B operation of the push-pull output stage in a three stage circuit capable of accepting a very large amount of over-all feedback. Provisions are available for matching any load impedance between the limits of 5 and 24 ohms.

35.4. Low Noise Transistor Microphone Amplifier

J. J. Davidson, *Radio Corp. of America, Camden, N. J.*

The attraction of transistors for use in low-level amplifiers has long been obvious. Such factors as size, weight, power consumption, and economy have indicated the potential superiority of transistors over vacuum tubes.

* Sponsored by the Professional Group on Audio. To be published in Part 7 of the 1957 IRE Convention Record.

Until recently, however the prime requirement of low noise factor could not be met with any consistency. Although transistors under optimum conditions appear inherently inferior to vacuum tubes under optimum conditions the difference is slight, and other factors, such as reliability and stability may swing the balance. Some trends and criteria for low noise design are discussed, including results on some experimental transistors. An experimental microphone amplifier is utilized as the embodiment of the design requirements.

35.5. Circuit Considerations for Audio Output Stages Using Power Transistors

R. Minton, *Radio Corp. of America, Somerville, N. J.*

This paper discusses design considerations for audio-frequency output stages using alloy-junction *p-n-p* power transistors. Optimum transistor operating conditions for practical circuit designs are given.

Both class A single-ended and class B push-pull power output stages are evaluated, and the effects of variations in source and load impedance are discussed. Methods of obtaining the desired stability of dc bias with variation in ambient temperature are described. Experimental data are presented in the form of curves of maximum power output power gain distortion and efficiency of a typical application using the new power transistor.

SESSION 36*

WED. 2:30–5:00 P.M.

WALDORF-ASTORIA JADE ROOM

Transistorizing Nuclear Instrumentation

Chairman: R. F. Shea, *General Electric Co., Schenectady, N. Y.*

36.1. Transistorizing Nuclear Instruments—A Status Report

R. F. Shea, *General Electric Co., Schenectady, N. Y.*

The present status of the use of transistors in nuclear instrumentation will be reviewed. Possible areas of application which are still untapped will be listed, and a discussion of the research necessary to foster transistorization to nucleonic instrumentation will be given.

36.2. Noise in Transistor Nucleonic Pulse Amplifiers

A. R. Jones, *Atomic Energy of Canada, Ltd., Chalk River, Ontario*

An experimental study of the high-frequency noise in surface barrier transistors has been made. It was found that above about 10-kc shot noise predominated. This noise followed the pattern predicted by Van der Zeil in its dependence upon standing currents and frequency. The application of these results to the design of a nucleonic pulse amplifier is discussed. In particular, a design for a preamplifier employing transistors is examined to see how the noise may be minimized without sacrifice of the required bandwidth. Also the choice of time constants employed in the shaping of the pulses in order to obtain the best energy resolution is considered.

36.3. Recent Advances in Transistorizing Reactor Controls

K. H. Klein, *Daystrom, Inc., Archbald, Pa.*

This paper will describe a transistorized reactor control system including in all-transistor scaler and some other transistorized developments that are to be carried out in an effort to reduce size and weight in reactor controls. Other instruments that don't lend themselves to full transistorization will also be described.

36.4. Transistorized Time-of-Flight Analyzer with Ferrite Core Memory

E. J. Wade and D. S. Davidson, *General Electric Co., Schenectady, N. Y.*

The neutron time of flight analyzer is one of the basic tools used by the nuclear physicist and various designs have been built which take advantage of continuing improvements in the electronic and computer fields.

The development of the random access ferrite core memory made it practical to greatly increase the number of storage channels while at the same time reducing the number of vacuum tubes.

Improvements in transistors have made it feasible to use them with a great saving in space and power requirements especially in computer-type circuits where the requirements are primarily switching which minimizes the necessity for close control of transistor characteristics and reduces the dissipation requirements.

Accordingly, a completely transistorized 256-channel analyzer has been designed and built which is housed with power supplies in a cabinet only 19 inches wide, $8\frac{3}{4}$ inches high, and 13 inches deep.

36.5. Transistorized Counting-Rate Meter and High-Voltage Supply

A. Pearlman, *Universal Atomics Corp., Westbury, N. Y.*

In order to provide a scintillation-counter-type survey meter suitable for medical and airborne ore-locating use, a light-weight transistorized system has been developed. The unit described weighs approximately 22 lbs. complete with scintillation crystal, photomultiplier tubes, and lead shield.

The counting-rate meter amplifier, discriminator, and high-voltage supply are transistorized and operate off self-contained batteries. However, an auxiliary ac power supply is incorporated into the instrument for operation from standard 115-volt 60-cycle power.

SESSION 37*

WED. 2:30–5:00 P.M.

WALDORF-ASTORIA SERT ROOM

Symposium on Applications of Computers in Biology and Medicine

Chairman: P. H. Mitchell, *Air Research and Development Command, Baltimore, Md.*

Panel Members: R. Pepinsky, *Dept. of Physics, Pennsylvania State University, University Park, Pa.*
M. Edin, *National Heart Institute, National Institutes of Health, Bethesda, Md.*
B. Chance, *Johnson Research Foundation, University of Pennsylvania, Philadelphia, Pa.*
J. W. Mauchly, *Remington Rand Univac, Philadelphia, Pa.*
R. S. Ledley, *Operations Research Group, George Washington University, Washington, D. C.*

Just as other standard electronic techniques have been applied to the solution of complex biological and medical problems computer techniques are developing rapidly in these fields. Some of the present and future applications to be discussed include:

1) The visualization of complex organic molecular structure.
2) Analog and digital computer representations of the dynamics of metabolism.
3) Medical data processing for correlative, diagnostic, and searching purposes.
4) The probable and the possible in computer applications.
5) Monte Carlo methods in cell multiplication processes.

SESSION 38**

WED. 2:30–5:00 P.M.

NEW YORK COLISEUM MORSE HALL

Color Television

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* Sponsored by the Professional Group on Nuclear Science. To be published in Part 9 of the 1957 IRE Convention Record.

* Sponsored by the Professional Groups on Medical Electronics and Electronic Computers. To be published in Part 4 of the 1957 IRE Convention Record.

** Sponsored by the Professional Group on Broadcast and Television Receivers To be published in Part 3 of the 1957 IRE Convention Record.

Chairman: W. O. Swinyard, *Hazeltine Research, Inc., Chicago, Ill.*

38.1. Developments in Color TV in Europe

C. J. Hirsch, *Hazeltine Corp., Little Neck, N. Y.*

An up-to-date review of proposals for color television system standards in Europe will be presented by the speaker, Chairman of the CCIR Television Preparatory Committee, U. S. Department of State, who has an intimate first-hand knowledge of this technical situation.

38.2. Brightness Enhancement Techniques for the Single-Gun Chromatron

R. Dressler, P. Neuwirth and J. Rosenberg, *Chromatic Television Laboratories, Inc., New York, N. Y.*

Single-gun color cathode-ray tubes must display color video information in a sequential manner. United States color signal standards utilize a subcarrier of 3.58 megacycles. At this frequency color gating for the single-gun display is accomplished with sine waveforms which contribute to a loss in light output.

This paper describes two techniques, "single-key-out double blue" and "chroma modulated 10.7 megacycles," which allow recovery of the light loss incurred by these gating waveforms. In order to describe the enhancement processes, basic light outputs from Lawrence tubes without gating will be described along with the simple tripler decoding technique which contributes a 66 per cent light loss. These enhancement techniques allow 50–60 foot lamberts light output from presently available tubes.

In addition, circuits and system errors will be discussed

38.3. Accuracy of Color Reproduction in the "Apple" System

J. B. Chatten and R. K. Gardner, *Philco Corp., Philadelphia, Pa.*

In the "Apple" system the mechanism of color selection is quite different from that of a color receiver system using a three-gun display tube. In the Apple system this mechanism is a sequential sampling process wherein the crt drive waveform, the transfer characteristic of the electron gun, the shape of the scanning aperture, and the stripe structure are all factors in defining the reproduced color.

An intensive study has been made of the relationship between the crt drive signal and the reproduced color wherein all the above mentioned factors have been considered. From this it is possible to make a comparison of color reproduction (both chromaticity and luminance) between an Apple receiver and an assumed "standard monitor," as implied by the FCC color television broadcast standards.

38.4. Recent Improvements in the Apple Beam Indexing Color Picture Tube

H. R. Colgate, C. P. Comeau, D. P. Kelley, P. D. Payne, and S. W. Moulton, *Philco Corp., Philadelphia, Pa.*

This paper covers some recent improvements in the Apple tube. Significant improvements in brightness and color saturation resulting from the use of unequal color line widths are described. Contrast improvements obtained by better black guard line materials are discussed. A description of changes in screen and index geometry which have eliminated certain receiver functions is included in the paper. Long-term life test results are presented.

38.5. An Advanced Color Television Receiver Using a Beam Indexing Picture Tube

R. A. Bloomsburgh, A. Hopengarten, R. C. Moore, and H. H. Wilson, *Philco Corp., Philadelphia, Pa.*

This paper describes a new receiver using a beam indexing display and includes circuit construction, and performance data. The receiver is designed to utilize the picture tube described in the preceding companion paper. Important design criteria will be discussed together with circuit examples. Complete information on receiver alignment is included.

SESSION 39*

WED. 2:30–5:00 P.M.

NEW YORK COLISEUM MARCONI HALL

Microwaves I—Components

Chairman: A. G. Clavier, *Federal Telecommunication Labs., Nutley, N. J.*

39.1. A Broadband Fixed Coaxial Power Divider

J. Reed and G. J. Wheeler, *Raytheon Manufacturing Co., Wayland, Mass.*

The design of a coaxial line power divider of any fixed power division ratio and maximally-flat performance is described. The performance of an actual model is tested over a 30 per cent band by the Deschamps method as well as other schemes and a comparison of these schemes described. The design includes a stub support so the device will stand high power. A refinement to the existing theory is discussed.

39.2. Broadband Waveguide-to-Coaxial Transitions

G. J. Wheeler, *Raytheon Manufacturing Co., Wayland, Mass.*

This paper describes three transitions from waveguide to coaxial line, each of which covers a frequency range of more than 30 per cent. These include:

1) A transition from WR 159 waveguide to 50 ohm coaxial line with a vswr $\leqq 1.14$ from 4400 to 7000 mc. This is a "normal" transition in that the coaxial line feeds into the center of the broad face of the waveguide.
2) A colinear end-on transition from RG 48/U waveguide to standard 50 ohm $\frac{7}{8}$ inch coax with vswr $\leqq 1.10$ from 2600 to 3700 mc.
3) A colinear end-on transition from 2.840 $\times$0.875 inches id waveguide to standard 50 ohm $\frac{7}{8}$ inch coax with vswr $\leqq 1.13$ from 2600 to 3800 mc.

39.3. Transmission Properties of Hybrid Rings and Related Annuli

H. T. Budenbom, *Stavid Engineering, Inc., Plainfield, N. J.*

Advances made in the transmission analysis of conventional hybrid rings since their invention are summarized. Some new properties of hybrid rings and related annuli are noted. Some new hybrid rings nonconventional in number of taps and/or perimeter, are described and analyzed. A method of using hybrid rings in tandem to attain improved conjugacy bandwidth and depth is given. Experimental data are included.

39.4. Development of Circularly Polarized Microwave Cavity Filters

C. E. Nelson and W. L. Whirry, *Hughes Aircraft Co., Culver City, Calif.*

The use of circularly polarized microwave cavities leads to a simplification in the art of microwave filter design. Only one cavity (wtih two coupling apertures) is required to produce a four-port waveguide filter that is a reflectionless diplexer (*i.e.*, bandpass and/or band elimination). A rectangular waveguide with one coupling aperture can excite a circularly polarized cavity mode by H_x and H_z or E_y and H_x coupling. The latter type of coupling can be accomplished through apertures in the side walls of a circular cylinder cavity, freeing the end plates for tuning and temperature compensation. For commercial use of these filters the TE_{112} cavity mode was chosen as the optimum degenerate mode on the basis of minimum cavity wall losses and maximum separation of unwanted cavity modes. Experimental test results at X-band frequencies are included for several of these cavities.

Several novel filters are introduced which use 3-db waveguide couplers and two apertures to excite a circularly polarized cavity mode. These filters are also reflectionless and have the same general properties as the other circularly polarized cavity filters.

39.5. Design of Improved Microwave Low-Pass Filters Using Strip-Line Techniques

Lt. R. A. Van Patten, *Rome Air Development Center, Griffiss Air Force Base, N. Y.*

* Sponsored by the Professional Group on Microwave Theory and Techniques. To be published in Part 1 of the 1957 IRE Convention Record.

Low-pass filters find application as components in narrow band transmitting, receiving and test equipment to control spurious responses, harmonic output, and interference. Strip-line low-pass filters are easily designed and give very satisfactory performance at a fraction of the cost of other types in the frequency range from 500 to 7000 mc. This report gives a design procedure for strip-line low-pass filters including two improvements over conventional designs.

It is shown that by cutting away a small portion of the dielectric material surrounding the fine conductor in the high impedance or inductive sections of the filter the stop band width can be effectively extended by as much as 100 per cent. A formula for the characteristic impedance of the resulting two dielectric, high impedance transmission line structure is derived. A method not involving stubs for realizing m-derived sections is given. The resulting m-derived sections have the advantage of smaller size and do not become antiresonant at approximately twice the cutoff frequency as do the quarter wavelength open circuited stubs commonly used. An approximate method for taking fringing capacitance into account is given. The problem of spurious responses caused by waveguide mode propagation is discussed and two solutions are offered.

39.6. Broad-Band Frequency Stabilization of a Reflex Klystron by Means of An External High "Q" Cavity

M. Magid, *Hughes Aircraft Co., Culver City, Calif.*

The cavity frequency stabilization system operating over narrow frequency bands described previously has been extended for 40 per cent bandwidth operation in rectangular waveguide. The development of a variable coupling type high "Q" cylindrical stabilization cavity and a compact phase shifter-mode suppressor required for the system is discussed. These components operate over the entire bandwidth of $1\times\frac{1}{2}$-inch waveguide. The system has been applied to two klystrons differing electrically. An improvement in the frequency stability of these klystrons by factors between 4 and 40 has been attained, with a small reduction in power output. The frequency stabilization system can be applied to most klystrons operating into $1\times\frac{1}{2}$-inch waveguide

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SESSION 40*

WED. 2:30–5:00 P.M.

NEW YORK COLISEUM
FARADAY HALL

Production Techniques

Chairman: J. J. Farrell, *General Electric Co., Syracuse, N. Y.*

40.1. The 14E Automatic Component "Wire-Wrap" Machine

H. F. Wilson, *Gardner-Denver Co., Grand Haven, Mich.*

Acceptance of solderless connections made by hand-held "Wire-Wrap" tools in the electronics industry has paved the way for a more automatic means of fabricating circuits. This method fastens pig-tail components by forming and wrapping the leads simultaneously, eliminating further operations such as lead straightening, cutting, and soldering.

By eliminating heat from the process and gripping components by the leads only during handling and wrapping, even the most fragile components are protected from damage during the process.

40.2. An Approach to Airborne Digital Computer Equipment Construction

P. E. Boron and E. N. King, *Hughes Aircraft Co., Culver City, Calif.*

This paper is a discussion of one method of building airborne digital equipment, making use of the unitized etched wiring plug-in philosophy and utilizing an all-etched wiring harness to make the large number of connections between plug-in units. Points of emphasis are miniaturization, reliability, small weight, accessibility, and manufacturability of the equipment.

40.3. An Automatic Dip Soldering Machine

V. O'Gorman, *United Shoe Machinery Corp., Beverly, Mass.*

An automatic high-production dip-soldering machine for printed circuit boards is described. The machine fluxes, preheats, dip-solders, cleans the residual flux from the boards, and unloads automatically at a rate of 1000 per hour,

The physical principles of the soldering process are discussed. The influence of these principles on the basic design of the machine and the adjustments required to effect the proper balance of the several process variables are described, as well as the experience obtained from its use in production.

40.4. Encapsulation of Electronic Circuits

R. Calicchia, *Rome Air Development Center, Griffiss Air Force Base, N. Y.*

RADC is actively engaged in a program aimed at developing experimental design data for engineers confronted with problems of selecting proper encapsulents for electronic equipment. This paper will indicate the quantitative effects of the encapsulating media upon the electrical characteristics of the embedment. Of major interest, is the work initiated on electrical performance of resistors, capacitors, inductors, and simple circuits at frequencies up to 250 mc. It was necessary in this work to investigate the electrical and mechanical properties of various resins in order to select the most suitable encapsulents for specific applications.

40.5. Development of Interconnecting Wiring

D. J. Keller, *Sperry Gyroscope Co., Great Neck, N. Y.*

Old style bulky interconnection harnesses are now being superseded by streamlined miniature versions which compact an almost unbelievable footage of wire into a given space. The ramifications of the problem, particularly in the interconnection of miniature components, has led to a categorized approach, which includes coverage of electrical noise and shielding philosophy, as well as physical and mechanical problems which must be anticipated. In order to understand and fully appreciate the depth of this problem, a brief history of early wiring is presented with graphic illustrations showing the relative improvements in the manufacture of wire, cable, and cabling techniques. Actual models are displayed showing the simple to complex relations which have evolved. As an aid to the systems engineer, a harness preparation sequence is shown, step by step, with an analysis of the problems which are introduced as the interconnections become more complex. Parallel items such as ground points, special connectors, adapters, markers, color coding, current carrying capacity, harness tapes, etc. are discussed with visual examples of each category. A prediction for the future is postulated.

SESSION 41*

THURS. 10:00 A.M.–12:30 P.M.

WALDORF-ASTORIA
STARLIGHT ROOF

Electronic Computers II—Symposium on Computers in Simulation, Data Reduction, and Control

Chairman: R. D. Elbourn, *National Bureau of Standards, Washington, D. C.*

A rapidly expanding class of computer applications that includes the simulation of complex systems in real time, on-line reduction of experimental data, and automatic process control is introducing new problems that were not met in the mathematical and business applications.

Problems of speed and control affect the design of the computer itself. For sufficient speed it may have to be wholly or partly analog or, if digital, it may have to be a special purpose rather than general purpose machine. The control may have to permit interruption for special tasks and then return automatically to a former task.

Communication between the computer and the rest of the system may involve problems of conversion between analog and digital data, of multiplexing many data channels into one computer channel, of smoothing or interpolating sampled data, or of preparing displays suitable for human beings.

The first two speakers will deal generally with these problems, then three speakers will describe their solutions in three specific applications:

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1) A large combined analog-digital simulator.
2) The digital control of machine tools.
3) The reduction of wind-tunnel data.

After these talks there will be a round table discussion of present and future solutions of these problems.

SESSION 42*

THURS. 10:00 A.M.–12:30 P.M.
WALDORF-ASTORIA
ASTOR GALLERY

Circuit Theory II—Transistor and Amplifier Circuit Design

Chairman: J. BRAINERD, *University of Pennsylvania, Philadelphia, Pa.*

42.1. Some Useful Techniques for Overcoming Frequency Limitations of Distributed Amplifiers

P. H. ROGERS, *University of Arizona, Tucson, Ariz.*, AND B. F. BARTON AND L. A. BEATTIE, *University of Michigan, Ann Arbor, Mich.*

A major limitation on the high-frequency capability of distributed amplifiers results from the presence of grid and plate lead inductances. These inductances approach series resonance with the input and output tube capacities of the tube, respectively, as the operating frequency range is increased. Negative mutual cancellation becomes increasingly difficult as the series inductance of the line sections is reduced in the interests of bandwidth. It is shown that the frequency capability of conventional circuits may be surpassed through the use of dummy line sections between tubes. It is shown that a constant $-K$ line gives nearly the maximum obtainable bandwidth. An amplifier with 4×150 A tubes and a cutoff of 490 mc is described.

42.2. Regeneration Effects in Double Tuned Band-Pass Amplifiers

P. BURA, *Canadian General Electric Co., Ltd., Toronto, Canada*

The amplitude and delay response of maximally flat band-pass amplifiers with double-tuned interstage circuits are distorted by the presence of unwanted feedback through the plate-to-grid capacitance.

It is shown that the amount of distortion introduced depends on a regeneration coefficient α. When α is sufficiently large oscillations will result. The critical value of α will be calculated for the double-tuned interstage circuits and compared with that for the single-tuned circuits.

The effect on the delay response is calculated and methods of flattening the delay and amplitude response are discussed.

42.3. A New Junction-Transistor High-Frequency Equivalent Circuit

R. D. MIDDLEBROOK, *California Institute of Technology, Pasadena, Calif.*

A small-signal equivalent circuit for a junction transistor is presented which is applicable to alloy or grown types of *p-n-p* or *n-p-n* transistors, and which is valid from dc up to twice alpha cutoff. The equivalent circuit is in the form of four short-circuit admittances, each of which can be represented by a simple network of lumped elements constant with frequency. The derivation is based on physical principles and takes into account base widening and collector barrier capacitance. Equations for the equivalent circuit element values are given either in terms of physical parameters or in terms of six practical measurements. The four-admittance representation is given both for common emitter and common base connections, and a relation between the common emitter and the common base cutoff frequencies is derived and experimentally verified. Measurements of the real and imaginary parts of the four admittances as functions of frequency for several transistors show excellent agreement with the values predicted by the equivalent circuit.

42.4. Circuit Applications of Semiconductor Junction Capacitance

F. H. DILL, JR. AND L. DEPIAN, *Carnegie Institute of Technology, Pittsburgh, Pa.*

This paper describes various applications of the voltage-dependent capacity of semiconductor junction diodes. The most promising applications seem to be those utilizing a voltage controlled sweeping oscillator. Some of these are frequency modulation, frequency control, search receivers, panoramic adapters, and spectrum analyzers in general. In these applications there are advantages to using the junction capacitance rather than reactance tubes or ferroelectric capacitances.

42.5. Pulse Circuit Applications of a New Semiconductor Device

R. A. STASIOR, *General Electric Co., Syracuse, N. Y.*

A new process high-frequency npn silicon transistor designed for military use offers characteristics well suited to pulse circuits. It permits high reliability, low cost direct coupled transistor logic circuitry operating at 500 kc. Other applications to be discussed will include multivibrators and pulse amplifiers.

42.6. Design of Junction Transistor Multivibrators by Driving-Point Impedance Methods

J. J. SURAN, *General Electric Co., Syracuse, N. Y.*

An analytical method for the design of junction transistor multivibrators by the use of two-terminal driving point techniques is presented. The synthesis method is based upon the point of view that the circuit design rather than the transistor properties should determine the operating characteristics of the multivibrator. Such factors as dc stability, parameter tolerances, frequency response characteristics, maximum switching speed, and trigger requirements are discussed.

It is shown that the two terminal design method may be used to

1) Completely determine by analytical means the dc design of the circuit for a given set of specifications,
2) Calculate the value of the coupling capacitors required to meet certain speed requirements,
3) Determine the mode of operation of the multivibrator, *e.g.*, astable, monostable or bistable,
4) Predict the maximum repetition rate at which the circuits may be driven or free-run,
5) Predict the minimum charge requirement for triggering the monostable or bistable circuits.

The design method reveals the differences which are important between silicon and germanium transistor multivibrators. In addition such factors as circuit efficiency as a function of temperature stability and parameter tolerances are discussed. Experimental verification of the theoretical results is presented.

SESSION 43*

THURS. 10:00 A.M.–12:30 P.M.
WALDORF-ASTORIA
JADE ROOM

Component Parts I

Chairman: L. KAHN, *Aerovox Corp., New Bedford, Mass.*

43.1. Ceramic Filter Capacitors for VHF and UHF

H. M. SCHLICKE, *Allen-Bradley Co., Milwaukee, Wis.*

"Feed Through" capacitors (FT) (fed through metallic shield) and "Stand-Off" (SO) capacitors (used without shield) have one electrode on ground while the other provides an undisturbed passage for dc or low frequency, but forms the short circuit terminal for very high frequency. They form an essential circuit element in grid and tank circuits and the dc supply points of amplifiers and oscillators, preventing undesired feedback, oscillations, interference, and radiation; or expressed positive terms, they are used for decoupling purposes.

At vhf and uhf, standard ceramic FT and SO, (nonceramic ones even more so) fail markedly to perform satisfactorily because of resonance (FT and SO) and because of inductive coupling effects (SO)

Generalizing from the superiority of discoidal (up to 3000 $\mu\mu$f only) over tubular FT's, the concept of minimizing or even eliminating

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phase shift to deresonate capacitors in the frequency range of interest is investigated systematically.

For the case of dielectrics alone, saw-tooth corrugations (unthreaded or threaded), untapered corrugations (impractical), and quasi-corrugations are evolved resulting in capacitors of arbitrarily high capacitance values and approaching the performance of ideal capacitors.

When ferrites are added, extremely simple new structures are obtained performing much better even than ideal capacitors, and if constructed as SO are also free of inductive coupling.

Finally a miniaturized, extremely effective low-pass filter for military equipment is described. It will replace bulky, unsatisfactory designs used so far.

Thus, a whole family of novel circuit elements has been developed having no presently available counterpart equivalent in performance or size. These elements will provide a definite improvement and simplification of commercial and military equipment working at vhf and uhf frequencies.

43.2. Manufacture and Measurement of Close Tolerance Temperature Compensating Ceramic Capacitors

N. Rudnick, *Glenco Corp., Metuchen, N. J.*

Temperature compensating ceramics from P100 to N750 are now blends of two parent compositions. Close tolerances derive from corrective additions of the appropriate parent to a presampled batch. A new glass coating has a reduced effect on the temperature coefficient and extends the temperature range. Coefficients are measured by an unique 1-mc bridge.

43.3. New Subminiature Metallized Paper Capacitors

P. P. Grad, *Aerovox Corp., New Bedford, Mass.*

A newly developed subminiature metallized paper capacitor is described. Its outstanding characteristics are a 50 per cent volume reduction from the smallest presently available units, a nearly flat temperature coefficient of capacitance, and very high insulation resistance even at elevated temperatures A new impregnating technique used for an unconventional impregnant for metallized paper capacitors is described.

43.4. The Use of Pulse Packages in Line-Type Pulsers

A. Luna, *Filtron Co., Inc., Flushing, N. Y.*

To be discussed is the natural development and the role of the pulse package in Radar transmitters today, and how in development work it materially reduces the time and effort required of the transmitter engineer—also how in production it can reduce the size and cost of the pulser and result in improved performance. The reasons for its even greater desirability in very narrow pulse work will be brought out.

To be discussed also is the role of the trigger pulse package, which can be of material help to engineers both in development work and in the product.

43.5. The Silver Oxide—Cadmium Alkaline Secondary Battery

P. L. Howard, *Yardney Electric Corp., New York, N. Y.*

A battery has been developed which substitutes cadmium for the zinc as negative active material in the silver-zinc secondary battery. By this change in negative the ability to accept CP charge and withstand over charging has been greatly improved.

This couple is more suitable for medium and low rate applications than for high rate use. The discharge voltage is approximately 1.2 volts per cell with 30 watt hours per pound and 1.5 watt hours per cubic inch. The cycle performance of this battery is rather uniform for several hundred cycles. Two to three thousand shallow cycles (50 per cent capacity) have been obtained from these batteries. The general characteristics of this system will be discussed.

SESSION 44*

THURS. 10:00 A.M.–12:30 P.M.

WALDORF-ASTORIA SERT ROOM

Industrial Electronics

Chairman: E. W. Leaver, *Electronic Associates, Ltd., Willowdale, Ontario, Canada*

44.1. The Canadian Mail Handling System and the Problem of Coding

M. M. Levy and A. Barszczewski, *Post Office Dept., Ottawa, Ontario, Canada*

The Canadian Post Office has under development an Electronic Automatic Mail Sorting System. The efficient operation of the system is made possible by use of a proper code and coding methods.

The proper names of towns, villages, and streets are converted into a special code suitable for electronic handling.

The process of coding is performed mentally by the operators according to a set of simple rules. The addresses of letters are read by the operators in special reading stations and mentally coded, the code is then marked on the envelopes by a special keyboard. Afterwards the remaining operations are performed completely automatically.

The prototype of the system is briefly described. The paper is dealing mainly with the coding problem and human factors involved in it. A clear account is given of various codes and coding aspects. Description is given of minimization of errors. The realization of a working system did depend to a large extent on suitable coding and therefore its importance is stressed.

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Although this paper is restricted to the specific application only, nevertheless the methods used have large potential possibilities in other fields where realization of electronic sorting and filing of data is essential.

44.2. Stabilized Magnetic Amplifier Circuits

H. W. Patton, *Airpax Products Co., Baltimore, Md.*

This paper describes dc to dc magnetic amplifier circuits which have effective input resistances of more than one million ohms and which can be made to have accuracies of better than a quarter of a per cent. These circuits are based on the potentiometric circuitry, a recent development in the magnetic amplifier art.

These newer potentiometric amplifier circuits have solved many of the tough design problems previously encountered, and have opened new paths towards designing reliable accurate, control and measurement equipments.

This paper reports recent work in this field, and by way of illustration shows what can be accomplished in terms of a typical design together with its actual performance characteristics.

44.3. New Techniques for the Control of Resistance Welding Machines

J. L. Solomon, *Sciaky Bros., Inc., Chicago, Ill.*

This paper describes a new and unique electronic control which has been applied to the control of the many functions required in the resistance welding process, and which has application to any system or machine requiring a series of timed controlled functions.

The control of resistance welding requires a series of accurately measured time intervals which follow in sequence for controlling the application of welding current and force to the material being welded. The timing circuits utilized in the past have definite shortcomings and limitations due to change in circuit components which affects the timing functions. A new concept of control is utilized, that of timing by counting cycles of the line frequency. This paper describes the use of the Dekatron glow transfer tube as applied to a system of control for resistance welding machines.

44.4. Pulse-Firing and Recovery-Time Characteristics of the 2D21 Thyratron

J. A. Olmstead and M. Roth, *Radio Corp. of America, Harrison, N. J.*

This paper describes the physical processes which occur within the 2D21 thyratron during pulse firing and recovery of grid control. Both of these characteristics depend upon retention or loss of grid control. This grid control is greatly reduced when positive ions are present within the tube. The positive ions surround the grid, forming a space-charge sheath which tends to neutralize the effect of external potentials applied to the grid.

In order to fire the 2D21 with short grid pulses (50 microseconds or less), the grid must be driven positive to speed the ionization process and the resulting loss of grid control.

Pulse firing is primarily a function of anode voltage, grid voltage and the grid-pulse duration.

In order to recover control of the 2D21 thyratron after conduction, the grid-terminal voltage must be sufficiently negative to reestablish grid control. Recovery time is primarily a function of anode voltage, anode current prior to extinction, and grid-terminal voltage. The grid bias and grid-circuit resistance combined with the afterglow grid current determine the grid-terminal voltage.

Illustrative data for both of these characteristics are presented.

SESSION 45*

THURS. 10:00 A.M.–12:00 NOON
WALDORF-ASTORIA
GRAND BALLROOM

Reliability Programs

Chairman: J. R. Steen, *Sylvania Electric Products, Inc., Woburn, Mass.*

45.1. Air Force Ground Electronic Equipment Reliability Improvement Program

J. J. Naresky, *Rome Air Development Center, Griffiss Air Force Base, N. Y.*

As the demands of modern warfare have dictated increases in electronic equipment complexity, reliability has been correspondingly decreased, thus necessitating the institution of a comprehensive program of reliability improvement in the Department of Defense. This paper describes the factors leading to the development of the program at the Rome Air Development Center and the methods of its implementation on radar and other ground electronic equipment developed by RADC.

The RADC Reliability Program—past, present, and future—is discussed. The general areas covered are: 1) Methods of educating design engineers on reliability; 2) development, verification and use of a reliability predication technique; 3) development of automatic monitoring equipment; 4) component and circuit reliability improvement techniques, and 5) insertion of quantitative reliability requirements into equipment specifications.

45.2. A Reliability Program

R. E. Kuehn, *International Business Machines Corp., Owego, N. Y.*

The introduction of complex electronic systems into general usage has made the organization of reliability engineering groups a necessity. This group can function best by reporting to the manager of engineering as an independent evaluation and service agency. The tasks of reliability engineering include the development and application of reliability prediction techniques; the operation of a failure reporting and analysis system; the selection, qualification, and application of components; the environmental and life testing of components, units, and systems, and the evaluation of systems on the bench and in the field for reliability, maintainability, accuracy, and operational suitability.

45.3. A Reliability Program for R and D Projects

E. F. Dertinger, *American Bosch Arma Corp., Garden City, N. Y.*

The proposed paper will describe a long-range reliability program which has been inaugurated during the initial design stage of developing and producing an inertial guidance system for ballistic missile application. This program represents, to the writer's knowledge, the first all-out attempt to "design-in" complete missile system reliability.

Considerable effort will be extended toward presenting the procedures and techniques developed for "comparative evaluation" of functionally-suitable component parts and "reliability qualification" of: 1) parts selected for design incorporation, 2) assemblies and major components, and 3) complete systems. The philosophy of Arma management as regards reliability and the support given to this program will be described.

45.4. The Role of Quality Engineering in Procuring and Producing Reliable Products

R. A. Hulnick, *International Business Machines Corp., Kingston, N. Y.*

To assure production of a reliable product, quality engineering must formulate for the manufacturer a plan which encompasses a design of acceptable reliability, adequate controls over procurement and processing, and techniques for continuous performance evaluation for the purpose of product improvement.

SESSION 46*

THURS. 10:00 A.M.–12:30 P.M.

NEW YORK COLISEUM
MORSE HALL

Symposium—Digital Techniques for Problems in Telemetering and Remote Control

Chairman: C. H. Hoeppner, Jr., *Radiation, Inc., Melbourne, Fla.*

46.1. A High-Speed Digital Data-Handling System

G. F. Anderson, *Radiation, Inc., Melbourne, Fla.*

This paper describes a high-speed digital data-handling system which provides digitizing, editing, and processing of pwm and fm/fm data This system digitizes a maximum of 22 channels of analog data at a channel-sampling rate of 22,000 data points per second. An overall accuracy of one part in 1024 is provided, utilizing a 10-bit binary straight code. Simultaneous sampling of the data to an accuracy of 33 microseconds is provided. Editing is provided by the Quick-Look analog recording system. The processing system generates an output code compatible with the IBM 650 computer; however, with slight alterations, the output format can be made compatible with other types of digital computers.

46.2. Magnetic Tape Playback and Digital Conversion of Telemetered Flight Data for Entry into Digital Computers

G. C. Dannals, *Radiation, Inc., Melbourne, Fla.*

Paper describes an automatic digital conversion and data processing system designed and built by Radiation, Inc. for the AC Spark Plug Division of General Motors Corp. Decommutated and separated pdm and fm/fm data recovered during magnetic tape playback of telemetry records is electronically sampled and converted to ten-bit binary code and further processed to suitable form for entry into high-speed digital computers. Data editing, intermediate recording, and processing control features are incorporated. Other salient features as regards system accuracy, high-speed handling, and operational flexibility are discussed.

46.3. Design Considerations for Super Speed Perforated Tape Digital Recording

J. Bellinger, J. T. MacNeill, and C. F. West, *Soroban Engineering Co., Melbourne, Fla.*

Until recently, techniques for recording digital data on perforated tape have been perfected to meet the requirements of the communication industry. The recorder described in this paper probably represents the first tape perforator designed for instrumentation as well as digital computer output data recording applications.

The design now permits recording of standard 5, 6, 7, or 8-hole code patterns to be reliably performed at controlled rates up to 240 codes per second. The perforator executes a basic

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recording cycle of one code in approximately 4 milliseconds. Since a recording cycle can only be executed on demand associated electronic control circuits will permit recording of random or a synchronous data at variable rates up to 240/second.

46.4. A High-Speed Binary-to-Binary-Decimal Translator

C. A. CAMPBELL, *Radiation, Inc., Melbourne, Fla.*

A high-speed translator has been developed which accomplishes binary-to-binary-decimal translation yet requires only about three vacuum tubes per bit.

By suitably arranging the feedback and trigger logic circuits the binary decades accept counts with weights of 1, 2, 4, 6, or 8. With minor circuit changes the counter will operate with any integral weight from 1 through 9.

Arranging these decades in cascade, inputs with weights of 16, 32, 64, etc., are accepted and totaled to decimal readouts, which may be in either binary or decimal presentation.

The present decade requires about five microseconds per binary digit for computation; however, the state of the art can allow an increase of at least tenfold in this speed.

46.5. Simplicity for Reliable Low-Cost Operation in a Digital Data-Processing System

J. W. PRAST, *Bell Aircraft Corp., Buffalo, N. Y.*

A simple and straightforward digital data-processing system for telemetering purposes was developed in 1954 and has been in operation since that time for processing special precision information during test flights of guided missiles.

Experience gained in operational use will be reported with emphasis on reliability and cost aspects.

The system features 0.1 per cent accuracy, inherent reliability, and low cost on the advantageous side with limitations in versatility as a disadvantageous feature; it was originally designed for processing fm-type information essentially not changing over a sampling interval of approximately 50 milliseconds. Improvements and additional applications for processing information in analog-voltage form and fully automatic operation will be discussed.

SESSION 47*

THURS. 10:00 A.M.–12:30 P.M.

NEW YORK COLISEUM MARCONI HALL

Millimicrosecond Instrumentation —Special Topics

Chairman: K. J. GERMESHAUSEN, *Edgerton, Germeshausen, and Grier, Inc., Boston, Mass.*

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47.1. Millimicrosecond Photography with an Electronic Camera

R. C. MANINGER AND R. W. BUNTENBACH, *Precision Technology, Inc., Livermore, Calif.*

Photography of detonation propagation, and growth and decay of electrical discharges requires ultrahigh speed cameras. Such a camera and some unique problems associated with its development are described in this paper. The camera consists of a specially designed image converter tube, associated pulse circuitry, and oscilloscope recording camera. The tube with its associated circuitry acts both as a shutter and as the means for moving images across the face of the stationary recording film. The camera can take a multiple framed sequence with arbitrary time spacing between frames and with exposure times during each frame as short as twenty millimicroseconds.

47.2. An Image Converter for High-Speed Photography

R. G. STOUDENHEIMER AND J. C. MOOR, *Radio Corp. of America, Lancaster, Pa.*

A developmental image converter tube having electrostatic focus, a shutter grid, and electrostatic deflection is intended for multiple frame photography of high-speed events with exposures as short as ten millimicroseconds. The image converter and its operating characteristics are described.

47.3. A Millimicrosecond Pulse Generator Using Secondary Emission Tubes

J. A. NARUD, *Harvard University, Cambridge, Mass.*

This paper describes a regenerative pulse circuit using a single secondary emission tube that is able to generate pulses having a rise time of 6 mμs and a width continuously variable from 25 mμs to 12 μs. First, a theoretical discussion of the circuit is given in which expressions for pulse width and resolving time are derived. The effect of the magnitude and shape of the applied trigger signal on the response of the circuit is also considered. At the end of the paper various practical realizations of the circuit are presented. Among others these include a millimicrosecond pulse generator and a fast pulse-height discriminator.

47.4. A Fractional Microsecond Light Source of High Intensity

R. L. FORGACS, *Ford Motor Co., Dearborn, Mich.*

Flash photography of rapidly moving objects requires a triggered light source with high intensity and short duration. This is particularly important for Schlieren and interferometer photography of shock waves where only a small fraction of the generated light can be used. Analysis of the various methods for discharging a capacitor through a spark gap light source indicates the superiority of a scheme in which a fast rising capacitor voltage produces gap breakdown. The major disadvantage of this method is that variation in the firing voltage results in fluctuations in light intensity and firing delay. In the developed circuit an auxiliary triggered gap with a unique electrode arrangement is used both to illuminate the light gap and to initiate the capacitor charging. This illumination causes the firing voltage on successive discharges to be constant within ±2 per cent. The light pulse duration is 0.18 and 0.53 μs for one and 10 joules energy respectively.

47.5. The Electrograph

R. A. BRODING, J. C. WESTERVELT, AND J. D. SCHROEDER, *Tulsa, Okla.*

A general purpose oscillograph is described wherein a completely dry processing, including sensitizing, exposure, development, and fixing of the record, is accomplished within the instrument as a continuous process. Trace vector speeds in the order of 600 inches per second are possible. The Electrograph combines the features of the conventional photographic oscillograph and the direct-writing oscillograph into one package. Such features as the use of high sensitive pencil type galvanometers, daylight exposure of the supply and take-up rolls, photographic timing lines, rectilinear recording, ability for traces to cross one another, viewing of the recording, permanent fixing and the completely processed record available on completion of the recording are possible for the first time.

SESSION 48*

THURS. 10:00 A.M.–12:30 P.M.

NEW YORK COLISEUM FARADAY HALL

Microwaves II—Switches

Chairman: A. G. FOX, *Bell Telephone Labs., Red Bank, N. J.*

48.1. Precision High-Speed Microwave Switch

W. E. FROMM, S. H. KLUG, AND K. S. PACKARD, *Airborne Instruments Lab., Inc., Mineola, N. Y.*

A three-port, single-pole, double-throw switch designed to transmit microwave power from either of two ports to the third or vice versa. The difference in transmission (or the difference in attenuation) of either of the possible paths of transmission has a required maximum variation of 0.003 db over any 40-megacycle band in the frequency range over which the instrument is designed to operate. The corresponding phase differential has a variation of less than 0.05 millimicroseconds over a 40-megacycle band. The cross-talk between the two paths is down by more than 70 db. The maximum vswr seen at either of the input ports is 1.06

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As presently designed, the instrument covers a 9 per cent frequency range in the *C*-band region. 10 db of attenuation exists through either path of transmission. The switching frequency is synchronous at 33 cycles per second. Seventy per cent of each cycle is useful time during which the transmission characteristics of one or the other of the two paths are constant and the vswr's are within their aforementioned limits. The remainder of the time is used as switching time.

In its present form the unit has waveguide input and output ports while the switching action is accomplished in strip line circuitry by means of a motor driven rotating attenuator.

48.2. Fast Acting Microwave Switch

H. H. Weichardt, *General Ceramics, Keasbey, N. J.*

This paper describes a novel mechanical microwave switch.

In its present embodiment the switch is primarily applicable to low-power circuitry. The switching time is of the order of one microsecond, and the stop-power attenuation is better than 60 db at all frequencies of the useful microwave spectrum The intrinsic insertion loss in the pass-power condition is negligibly small, and the total insertion loss can be kept negligibly small over a very wide frequency band by the use of proper input and output transitions. The short switching time was obtained by using an elastic inner conductor in a slab or strip transmission line, which upon a small longitudinal displacement of one end experiences a much larger lateral displacement of the center of the section and thereby contacts the outer conductors causing a very effective short. The driving force is obtained from a greatly simplified relay structure.

Due to the very small motion of all moving parts and the absence of frictional joints, the switch has shown exceptional good long-life properties.

48.3. High Speed Ferrite Microwave Switches

G. S. Uebele, *Hughes Aircraft Co., Culver City, Calif.*

A microwave circulator utilizing ferrite elements can be converted into a fast acting microwave switch by placing the ferrite in a pulsed magnetic field. The operation of the circulator may be based on the Faraday rotation phenomenon or on the nonreciprocal phase shift observed in a ferrite loaded rectangular waveguide. Problems in the design of the microwave structure as well as the electronic driving circuitry are discussed. Various techniques for the reduction of eddy currents in the waveguide are presented and the performance characteristics of various switches given.

48.4. An L-Band Ferrite Coaxial Line Modulator

B. Vafiades and B. J. Duncan, *Sperry Gyroscope Co., Div. of Sperry Rand Corp., Great Neck, N. Y.*

A new *L*-band modulator is described which utilizes low saturation magnetization ferrites to achieve a high percentage modulation over an eight per cent bandwidth. The device is designed in $\frac{7}{8}$ inch coaxial line, and modulation is affected by alternately biasing the ferrite into—and away from—gyromagnetic resonance using a longitudinally applied magnetic field. A thin walled tube of ferrite aluminate is located concentrically on the coaxial line center conductor and its saturation magnetization is such that operation is from zero field to resonance. Two concentrically wound coils are used to independently achieve ferrite biasing at the midpoint of the resonance curve and to achieve amplitude modulation. Design theory leading to the development of the modulator is presented. Information is likewise included on the pertinent physical and electrical characteristics of the modulator.

48.5. Ferrite Microwave Detector

D. Jaffe, J. C. Cacheris, and N. Karayianis, *Diamond Ordnance Fuze Labs., Washington, D. C.*

By inclusion of certain second-order terms in Polder's permeability tensor a nonlinearity results which predicts detection of an amplitude modulated microwave signal. The amplitude of the demodulated signal is a function of applied dc magnetic field and increases up to fields corresponding to ferromagnetic resonance where the variation is of the normal dispersion form. The detected low frequency field magnetostricts a ferrite rod the vibration of which is observed by means of a polarized $BaTiO_3$ ceramic rod bonded to the ferrite. The length of the composite rod is adjusted for mechanical resonance. Experimental results have verified the predictions of square law detection, dependence of the phase of the low frequency field on the sign of magnetization, and the monotonic increase of demodulation with increasing bias field.

SESSION 49*

THURS. 2:30–5:00 P.M.

WALDORF-ASTORIA STARLIGHT ROOF

Electronic Computers III—Mainly Analog

Chairman: J. D. Noe, *Stanford Research Institute, Menlo Park, Calif.*

49.1. Computation with Pulse Analogs

N. Rubenfeld, *W. L. Maxson Corp., New York, N. Y.*

A special purpose semidigital computer has been built to handle a computation involving two analog frequencies and an analog voltage using novel techniques. The equation to be solved is

$$f_x = \frac{E}{f_a} \times f_b.$$

The computation is done in two basic steps; the first step is computing a repetition rate $f_r = E/f_a$ and the second step is multiplying two frequency analogs, $f_r \times f_b$. The entire computer is built using basic blocks, such as, flip-flops, gates, blocking-oscillators, and is completely transistorized. Because of the flexibility of the basic concepts, the dynamic range of the computer is virtually unlimited.

49.2. A Cyclic Digital-to-Analog Decoder

G. H. Myers, *Rome Air Development Center, Griffiss Air Force Base, N. Y.*

This paper describes a counting decoder which converts a binary number into a duration-modulated pulse many times in a computing cycle without sacrificing the economy of an ordinary, basic decoder. The device, which is part of the TRADIC computer, uses only transistors and achieves its features by using the "cyclic" nature of binary numbers. That is, if a binary number is placed in a register and a fixed amount is continually subtracted from it, the original number will reappear after a constant time interval. Decoding the same number many times has the effect of giving the decoder a considerably greater bandwidth, which is an important consideration in control or servomechanism problems. The decoder also has certain other features which make it desirable in control applications.

49.3. An Automatic Analog Computer Method for Solving Polynomials and Finding Root Loci

L. Levine and H. F. Meissinger, *Hughes Aircraft Co., Culver City, Calif.*

Various analog computer techniques are available which provide the means for rapid solution of polynomials with an accuracy suitable for engineering purposes. Methods heretofore described in the computer literature, however, have the shortcoming of requiring a step-by-step procedure for finding the roots.

In this paper a new analog technique is discussed by which the roots are determined automatically. This is an application of the "method of steepest descent." A suitably chosen function W is minimized in the computer by a continuous adjustment of the coordinates of a point in the complex z plane until a stable equilibrium is reached. This corresponds to a root of the polynomial. In a polynomial of nth degree n such equilibrium points can be found. The coordinate adjustment follows the gradient of the function W and therefore leads to the minimum at the fastest possible rate.

The computer may be operated in two modes: 1) searching for individual roots from points arbitrarily chosen in the complex z plane, 2) tracking the roots while coefficients of the polynomial are being varied. The latter mode is ideally suited for plotting root loci in the complex frequency plane.

This paper contains a discussion of mathematical and practical aspects of the steepest descent method and gives several alternative computer circuits. Illustrative examples of steepest descent paths and root loci obtained on the computer are included.

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49.4. Magnetically Controlled Counters

E. A. SANDS, *Armonk, N. Y.*

A magnetically controlled counter will be described in which the count determining circuit is a pair of magnetic cores. A simple theoretical analysis will be made using the principles of equivalent core impedance. Some practical circuits will be shown, and deviations from predicted behavior will be discussed. Methods of designing units to produce reliable counts from scale 2 to scale 16 will be indicated. Means of presetting will be pointed out, and practical limitations on the use of the device will be explained.

49.5. Systematic Tracing of Discrepancies in Analog Computers

M. PLOTKIN, *Naval Air Development Center, Johnsville, Pa.*, AND E. GROSSWALD, *University of Pennsylvania, Philadelphia, Pa.*

Large analog computers are for the most part used in control, or closed loop, problems. In problems of this sort an error in one location, whether due to incorrect plugging or to a faulty component, causes errors throughout the machine. Should the errors result in observed discrepancies, by comparison of the machine output with a reference solution either obtained independently or produced earlier by the same computer, it is sometimes difficult in closed loop problems to find the cause. This paper proposes a method for locating systematically the source of such discrepancies.

SESSION 50*

THURS. 2:30–5:00 P.M.

WALDORF-ASTORIA ASTOR GALLERY

Circuit Theory III—Network Design Techniques

Chairman: L. A. ZADEH, *Institute for Advanced Study, Princeton, N. J.*

50.1. Pulse-Forming Networks Approximating Equal-Ripple Flat-Top Step Response

A. D. PERRY, *Bell Telephone Labs., Inc., Murray Hill, N. J.*

A simple iterative procedure of analog computation yields a set of two-terminal networks whose step responses approximate flat-top pulses in an approximately equal-ripple manner with ±0.1 per cent ripple. Digital computations and experimental studies verify the designs.

The approximation is carried out directly in terms of element values for a conventional negative-mutual PFN. The procedure is flexible enough to allow such additional constraints as equality of capacitors and/or simple nonlinear loads. Designs have also been carried out in which secondary and tertiary couplings were prescribed by the configurations of the coils. Specified, finite Q's are easily accommodated.

The singularity patterns of the networks have an intriguing regularity which has not yet been adequately exploited.

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50.2. Interstage Network Design with Practical Constraints

B. F. BARTON, *University of Michigan, Ann Arbor, Mich.*

A common method of interstage design, based on prototype circuits with all zeroes of transfer at infinity, leads to low-pass and band-pass circuits containing inductances without shunt capacitance. These coils and therefore the theoretical response become increasingly difficult of realization as the interstage impedance level is raised in the interests of gain. The present paper demonstrates design procedures leading to circuits in which all coils have shunt capacitance. The resulting networks may have either maximally flat or Tchebycheff pass band shapes. The networks have zeroes of response at real frequencies which may be useful in filter applications. Measured characteristics illustrating the advantages of these circuits are presented. Design curves are included.

50.3. Synthesis of Lumped Parameter Precision Delay Line

E. S. KUH, *University of California, Berkeley, Calif.*

In the design of a delay line one can break down the problem into two parts: first, to provide the required time delay and bandwidth with a network as simple as possible, and secondly, to have a good time response. This paper presents such a design technique for precision time domain applications. The network obtained is a tandem connection of a low-pass ladder which provides the shape of the time response and all pass bridge structures which give the desired time delay.

The approximation to the ideal delay function is based on the potential analog method in both cases. A method of estimating the time domain error from the frequency domain error is used to determine the maximum permissible phase deviation from linearity of the all pass network.

50.4. On the Approximation Problem in Filter Design

A. PAPOULIS, *Polytechnic Institute of Brooklyn, Brooklyn, N. Y.*

The problem of determining the network function of a filter of a certain order with an amplitude characteristic having the smallest possible "cutoff" interval for a given variation in the stop-band and pass-band, is considered. It is shown that the optimum characteristic has the equal ripple property in the stop band and the pass band, and that it is unique. From the uniqueness a simple relationship between the zeros and poles of the corresponding network function is established, and a method results for the determination of this function. The reduction in the cutoff interval, gained by limiting the stop band, is evaluated.

50.5. Recent Advances in the Synthesis of Comb Filters

W. D. WHITE AND A. E. RUVIN, *Airborne Instruments Laboratory, Inc., Mineola, N. Y.*

Recent developments in radar and allied fields have placed increasing emphasis on the demand for comb filters having carefully controlled characteristics. This paper reviews the synthesis procedures used in the design of such filters including an experimental verification of certain selected examples. The techniques shown are applicable not only to MTI filters having controlled velocity response, but also to video integrators for signal-to-noise enhancement. Emphasis is placed on an analogy between comb filters and conventional low-pass, and high-pass filters. This analogy permits one to draw on the wealth of information in the conventional filter design art.

50.6. Explicit Formulas for Tchebycheff and Butterworth Ladder Networks

L. WEINBERG, *Hughes Research Labs., Culver City, Calif.*

Green found the closed-form formulas for the element values in a resistance-terminated ladder network that has a maximally-flat (Butterworth) or equal-ripple (Tchebycheff) characteristic. These formulas apply only when all the zeros of the reflection coefficient ρ are chosen to lie in one half-plane. For $D_1=1$ and for n odd, a matched symmetrical network is obtained by the use of Green's formulas. For the case of n odd and any value of input-to-output resistance ratio, new formulas have been found for the element values when the zeros of ρ are chosen to alternate in the left and right half-planes. The networks obtained are related to the symmetrical ones given by Green's formulas for n odd and $D=1$.

SESSION 51*

THURS. 2:30–5:00 P.M.

WALDORF-ASTORIA JADE ROOM

Component Parts II

Chairman: A. W. ROGERS, *Signal Corps Eng. Labs., Fort Monmouth, N. J.*

51.1. Thermistors for the Gradual Application of Heater Voltage in Thermionic Tubes

J. J. GANO AND G. F. SANDY, *Massachusetts Institute of Technology, Lincoln Lab., Lexington, Mass.*

Thermistors, which are thermally-sensitive resistors having large negative temperature coefficients of resistance, can be aptly used for

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the gradual application of heater voltage in thermionic tubes, thus diminishing thermal transients and reducing mechanical failures. Commercially available units in washer form and properly mounted in stacks can accommodate heater loads up to 1200 watts. One stack can be used to limit the current at any instant to less than 120 per cent of normal for a wide range of loads. The method of determining the rating of a thermistor and the number required in series connection is also presented.

51.2. New Levels of Performance for General Purpose Resistors in Army Applications

R. A. Osche, *Signal Corps Engineering Labs., Fort Monmouth, N. J.*

A critical life evaluation, based on 7,000,000 resistor-hours, will be reviewed, together with the electrical, mechanical, and environmental attributes and the performance characteristics and deficiencies of general purpose (carbon composition) fixed resistors. It will be shown how new levels of performance for general purpose resistors, via Signal Corps development effort, have been obtained without sacrificing the size and mass producibility features of the composition types. The new performance level evaluation is based on 15,000,000 resistor-hours.

51.3. Measurement and Effects of Error Rate in Precision Potentiometers

S. B. Rasmussen, *Helipot Corp., Newport Beach, Calif.*

Linearity tolerance, the usual designation for potentiometer accuracy, is inadequate for predicting accuracy of rate systems or servo differentiators. A new figure of merit, called error rate tolerance, is proposed. Mathematically, error rate is a derivative of linearity error.

Several means for measuring error rate have been investigated, including a servo differentiator, which has proved superior in laboratory tests.

Inherent damping in a servomechanism tends to attenuate errors due to error rate. In a position servo, high error rates may lead to intermittent instability.

The figure for error rate is useful in estimating the frequency content of the linearity error signal, and in predicting variations in the loop gain of servomechanisms.

51.4. Theory, Measurement and Reduction of Precision Potentiometer Linearity Errors

F. Fritchle, *Helipot Corp., Newport Beach, Calif.*

Conventional engineering has in the past reduced potentiometer errors to a great degree. However, future reduction of residual errors will be accomplished only by analytical study of these errors.

There are four possible sources of linearity error in a potentiometer:

1) resistance wire nonlinearity;
2) machine winding errors;
3) mechanical or potentiometer geometry errors; and
4) electrical loading error from internal leakage.

Each of these errors is discussed and equations are given, the study of which indicates the parameters that are most critical.

Photos and typical recordings are shown of three newly developed machines for measuring these errors.

Methods of reducing each of these errors are discussed.

51.5. Vibration and Shock Resistant Relay Designs

A. P. Boylan, *Signal Corps Eng. Labs., Fort Monmouth, N. J.*, and J. L. Pfeffer, *Struthers-Dunn, Inc., Pitman, N. J.*

Subminiature general purpose and sensitive relays combining the desirable features of ruggedness, compactness, contact multiplicity, high contact current capacity, vibration, shock, and centrifugal acceleration resistance, heretofore unavailable in commercially procureable relays, have been developed under the recently completed Signal Corps program with Struthers-Dunn, Inc. These structures were designed specifically to fill an urgent need of missile and airborne equipment manufacturers, for sensitive and general purpose relays.

This paper will discuss the development goals of this program, the approach employed by the contractor, the problems encountered and the eventual solutions, the design parameters established as the best means of satisfying the severe environmental requirements, the performance thresholds of the developed structures, and the contributions which this program has made in advancing the state of the relay art.

SESSION 52*

THURS. 2:30–5:00 P.M.

WALDORF-ASTORIA SERT ROOM

Analysis and Techniques for Improved Reliability

Chairman: G. B. Carter, *International Business Machines Corp., Kingston, N. Y.*

52.1. Guided Missile Reliability vs Complexity

S. W. Lichtman, *Hughes Aircraft Co., Culver City, Calif.*

Reliability by the Poisson law of random chance failure is related to the exponential product of number of component parts in series and average failure rate per component part. Attempts have been made to express missile reliability in terms of total number of parts and in terms of key functional parts, corresponding to highest failure rates. The first, strictly complexity approach, leads to uncertainty regarding how exhaustive to make the parts count and to ambiguity concerning the lumping of similar parts into manageable categories. The latter approach yields results compatible with the first method but avoids these ambiguities. Since key functional parts are related to excellence of engineering and to production accomplishments, missile reliability is intrinsically more identified with product maturity than with total parts count.

52.2. Narrow Limit Gage Sampling Procedure

H. G. Harding and S. Price, *International Business Machines Corp., Kingston, N. Y.*

Manufacturers report that narrow limit (NL) gage sampling procedures are gaining in importance as the preferred method for quality-sampling of machined piece-parts. This advance in popularity of the NL technique is attributed to the increased sensitivity of measurement, and the saving in time, as compared with the normal sampling procedure specified in MIL STD 105A. In the "Proposal for a Narrow Limit Gage Sampling Procedure," the NL Technique is applied, for the first time, to the requirements of Incoming Inspection. By means of typical operating characteristic (OC) curves there is demonstrated that the NL technique, as applied to incoming inspection, effects the following results: 1) reduces incoming-inspection time by 50 per cent, 2) guarantees a quality assurance that is equal to MIL STD 105A, 3) rejects are disclosed at a more rapid rate than is true of normal sampling procedures, and 4) provides a concrete means for establishing a vendor-rating. In the presentation of the "Proposal for a Narrow Limit Gage Sampling Procedure," the applied technique is particularly slanted to incoming-inspection processes covering large lots of electrical and electronic components.

52.3. Increased Reliability through DC Overpotential Testing of Electronic Components

V. Wouk, *Beta Electric Corp., New York, N. Y.*

The use of high voltage dc for checking the insulation characteristics of electronic components, particularly those used in high voltage circuits, is shown to have important advantages over ac testing.

By means of proper interpretation of resisttance characteristics, component failures can often be anticipated. The technique of testing with high voltage dc, which is of growing importance in the electric power field, is offered for consideration in the electronic field.

Specific applications to capacitors are recommended as a worthwhile project for the radio-electronic industry to consider. Some typical dc test equipment is described.

52.4. Reliability Prediction Technique for Use in Design of Complex Systems

H. E. Blanton, *Hycon Eastern, Inc., Cambridge, Mass.*

A relatively simple reliability-prediction technique has been developed which can be instituted during the early stages of the design of complex systems. Through the use of *reliability diagrams* (obtained by modifying engineering block diagrams) and basic rules from

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* Sponsored by the Professional Group on Reliability and Quality Control. To be published in Part 10 of the 1957 IRE Convention Record.

probability theory, *reliability formulas* for proposed designs are derived. Effects of secondary failures and variations in requirements for successful performance are included. By evaluating the reliability formulas using the best available component-reliability estimates, alternative designs can be compared and the need for redundancy or component improvement is established. An example based on an airborne telemetering system illustrates the technique.

52.5. Analysis and Engineering Study of the Environmental Vibrations and Shock Characteristics of a New Military Airborne Gimbaled Equipment

D. Ehrenpreis, *David Ehrenpreis, Consulting Engineers, New York, N. Y.*

The outline of the analysis, engineering study, and theoretical investigation of the steady-state vibrations and sudden impulse shock dynamic characteristics of a new military airborne system are presented. Certain important natural frequencies and responses due to dynamic inputs are determined based upon this analysis of the complex framework.

SESSION 53*

THURS. 2:30–5:00 P.M.

NEW YORK COLISEUM
MORSE HALL

Symposium—Low Level Multiplexing for Telemetering and Remote Control

Chairman: C. H. Doersam, Jr., *Sperry Gyroscope Co. Inc., Great Neck, N. Y.*

53.1. Low Level Signal Multiplexing

D. W. Hill and A. S. Westneat, Jr., *Applied Science Corp. of Princeton, Princeton, N. J.*

This paper discusses system criteria for multiplexing a group of balanced milivolt data sources, with particular emphasis on commutator performance and on amplifier characteristics. Certain practical vacuum tube circuit applications are described, while development trends, involving greater uses of transistors, are discussed.

* Sponsored by the Professional Group on Telemetry and Remote Control. To be published in Part 5 of the 1957 IRE Convention Record.

53.2. A Low-Level Electronics Switch

E. Dorsett, *Radiation, Inc., Melbourne, Fla.*

Fundamental limitations in certain electronic switching methods render them completely unsatisfactory for applications in the microvolt region. The development of a suitable switching method employing solid state components involved investigation of numerous alternative methods. Environmental requirements, miniaturization, stability, linearity, and efficiency were prime considerations in the development, which resulted in a switch with a wide variety of possible applications. The switch developed was evaluated in the Laboratory and under operational considerations as a component in an airborne telemetry system. Data assembled during these evaluations are presented, along with photographic slides and a display of the equipment.

53.3. A Unique Wide-Band Transistorized Pulse Amplifier

W. T. Eddins, *Radiation, Inc., Melbourne, Fla.*

A transistorized amplifier for feeding analog voltage samples into a high-speed analog-to-digital converter is described. Due to the nature of the signal, a dc amplifier is found necessary, but good transient response, stability of gain, and low dc drift must be maintained. To provide good isolation, a high input impedance must be obtained, but output impedance must be kept low.

A unique method of applying negative feedback is used to obtain stability of gain, low output impedance, and wide bandwidth, and yet maintain exceptionally high input impedance. DC drift is minimized through the use of balanced input circuits, a thermistor, and a novel method of maintaining constant temperature about transistors.

The impact of transistors upon the field of dc amplifiers is discussed.

53.4. Completely Transistorized Strain Gage Oscillator

W. H. Foster, *Electronic Eng. Co. of California, Los Angeles, Calif.*

Associated with flight testing of aircraft and missiles is the problem of telemetering and/or recording stress information. Such data are usually gathered by a resistive type strain bridge transducer that converts stress variations to voltage level changes. The output of such a bridge is not directly compatible with fm telemetering or magnetic tape recording equipment. Accordingly, it is necessary to employ a converter for changing amplitude varying data to frequency varying data, thus allowing fm telemetering or magnetic tape recording of the data.

Described herein is a completely transistorized strain gage oscillator for accomplishing this conversion. This unit has been designed and tested in the laboratory, and the first units are now under construction. Its primary use is in conjunction with a resistive type strain bridge. The frequency of oscillation of the strain gage oscillator is caused to deviate as a linear function of bridge strain by injection of the bridge output signal into the local feedback loop at a point where it is in quadrature phase with the oscillator signal. The transistorized strain gage oscillator should prove to be a very practical working unit which occupies a volume of only 3.5 cubic inches and which operates over a broad ambient temperature range with long life expectation. The prototype has undergone extensive temperature stability testing throughout the temperature range from −55°C to +100°C. The specifications of the transistorized strain gage oscillator are comparable to those of high quality vacuum tube predecessors, but a distinct improvement over vacuum tube models is realized in the reduction of power consumption by a factor of 95 per cent.

SESSION 54*

THURS. 2:30–5:00 P.M.

NEW YORK COLISEUM
MARCONI HALL

Instrumentation II

Chairman: W. H. Fenn, *Hughes Aircraft Co., Culver City, Calif.*

54.1. Low Level Transistorized DC Amplifier With Improved Stability

A. Warnick and C. N. Savage, *Ford Motor Co., Dearborn, Mich.*

An analysis of the critical factors in the design of differential-transistor amplifier with dc stability and noise factor suitable for use with microvolt signals is presented. A successful design using two differential stages and a complementary output stage is described. The problems encountered in the selection of appropriate components are discussed. An analysis and detailed performance data are presented for the amplifier without feedback, and with multiloop feedback. The procedure for measuring the data presented is outlined.

54.2. A Unique Standard-Frequency Multiplier

J. K. Clapp and F. D. Lewis, *General Radio Co., Cambridge, Mass.*

A 10,000:1, four-stage multiplier utilizing quartz-controlled triode oscillators and an external cavity-controlled klystron oscillator as highly selective narrow-band filters is described.

Results of experimental tests of performance of phase-locked quartz-crystal and cavity klystron oscillators are given. The remaining phase jitter and noise are far below the levels found in usual multiplier circuits.

Phase comparison tests of two such multipliers operating from a single 100-kc frequency standard are described, and results obtained are given in photographs of the cro display.

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A novel method of separating and observing the effects due to hum frequencies is briefly described. Results are shown in photographs.

54.3. Measurement of the Complex Permeability of Magnetic Materials Over the Frequency Range of 50 to 500 Megacycles

I. Bady and R. J. Franklin, *Signal Corps Eng. Labs., Fort Monmouth, N. J.*

Four methods for measuring complex permeability at very high frequencies are described. They are based on the use of a high-frequency Q meter, cavity resonator, very-high frequency bridge, and slotted line. A feature common to all methods is that the sample holder is coaxial, and the sample is in the shape of a cylindrical ring. Test procedures and formulas are given. Sources of error and relative advantages of the methods are discussed. Measurements of several samples by the different methods show excellent agreement in almost all cases and the discrepancies which do occur are accounted for by sources of error discussed in the paper.

54.4. An Automatic Impedance Plotter Based on a Hybrid-Like Network with A Very Wide Frequency Range

C. B. Watts, Jr. and A. Alford, *Alford Manufacturing Co., Boston, Mass.*

In this paper is described an instrument which measures impedance and presents it in the form of a trace on a Smith Chart. Impedance plotters of this type work over wide frequency ranges, for example, 50–250 mc or 180–900 mc.

This automatic impedance plotter obtains its rf information from a hybrid-like network, which compares an unknown impedance with a standard impedance. A reference signal of constant amplitude and a smaller signal from the hybrid-like network are fed into a polar displayer. The smaller signal is essentially proportional to the reflection coefficient of the unknown impedance with respect to the standard load. The polar displayer is a network which converts the relative amplitude and the phase of the smaller rf signal into two audio frequency square waves which can be applied to the two axes of an oscilloscope or a two-axis recorder to obtain a direct polar display of the rf vector.

The automatic impedance plotter has been found to be very useful in the development of rf loads, switches, and of other devices which are intended to introduce small reflections. Reflections as small as those equivalent to 1.01 swr can be observed. All measurements can be readily referred to the characteristic impedance of a standard rigid line.

54.5. Automatic Indication of Receiver Noise Figure

A. J. Hendler and F. G. Haneman, *Airborne Instruments Lab., Inc., Mineola, N. Y.*

A general technique which provides an automatic and continuous indication of receiver noise figure is described. A device utilizing this technique employs modulated gaseous discharge noise sources and post detection synchronous integration allowing a continuous and direct-reading indication of noise figure.

The advantages of the automatic noise figure indication over conventional manual noise figure measurements are discussed as well as the relative accuracy of the two measurements. Techniques for the determination of the optimum design parameters for crystal mixers, traveling wave tubes, and rf amplifiers are also outlined.

Using the same techniques an instrument was developed which provides a continuous indication of radar receiver noise figure during normal radar operation. A pulse modulated noise signal, synchronized with the radar trigger, is injected into the receiver at the end of alternate radar sweeps. The signal is attenuated by a directional coupler; the added noise therefore causes negligible system deterioration.

54.6. High Precision Sawtooth Generator

L. J. Torn, *Airborne Instruments Lab., Inc., Mineola, N. Y.*

In the field of radar data processing applications frequently arise for ultraprecise single-scale timing devices. Typically, such requirements occur in the time demodulation process involved in the conversion of radar video time data into the equivalent range data.

Since early in World War II, sawtooth generators have been used as the time base for this demodulation process. These devices have previously been limited to accuracies in the order of one part in one thousand or less. Further: they require frequent recalibration and trimming, at best a tedious and difficult procedure.

Recent military requirements for higher accuracies, coupled with extreme reliability and stability, have led to a development program for a high-precision sawtooth generator. The new device was required to be accurate to better than one part in four thousand over long periods of time, without use of trimming controls of any type. In addition it was required that accuracy be maintained under field environmental conditions.

The theory and circuit development required for this new time-base generator are presented in this paper. As will be seen from the discussion, the nature of the requirements is such that the final development was forced to overcome the difficulties inherent in both high-stability dc amplifiers and high-frequency feedback amplifiers.

SESSION 55*

THURS. 2:30–5:00 P.M.

NEW YORK COLISEUM
FARADAY HALL

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* Sponsored by the Professional Group on Microwave Theory and Techniques. To be published in Part 1 of the 1957 IRE Convention Record.

Microwaves III—General

Chairman: E. Weber, *Polytechnic Institute of Brooklyn, Brooklyn, N. Y.*

55.1. The Optimum Spacing of Bead Supports in Coaxial Line at Microwave Frequencies

D. Dettinger, *Wheeler Labs., Great Neck, N. Y.*

In coaxial transmission lines, the inner conductor is commonly supported by dielectric beads spaced at intervals along identical sections of line. At microwave frequencies, where the bead spacing is large compared with the wavelength, there result sharp peaks of reflection corresponding to reinforcement of the reflections of individual beads. Assuming that the reflections of the beads themselves have been reduced to a uniform minimum by careful design and production control, it is advantageous to disperse the beads in each section so as to reduce the cumulative reflection peaks. A dispersal has been found which is believed to yield the minimum value of peak reflection.

55.2. Multiple-Line Directional Couplers

J. P. Shelton, Jr., *Melpar, Inc., Falls Church, Va.*

The problem of many directionally coupled parallel waveguides is considered from the aspects of continuous and discrete uniform coupling. The case of a finite number of continuously coupled lines is solved by a normal mode transformation. This case is extended to an infinite number of lines, and a Bessel function solution is obtained. A comparison of solutions for finite and infinite sets of coupled lines indicates that the Bessel function solutions are sufficiently accurate for most practical systems. Discrete coupling is considered, and it is shown, by means of scattering matrices and normal modes, that perfect match and directivity for a multiple-line directional coupler are not theoretically possible, except in the limit of very small coupling per aperture. Experimental verification is given for a flexible arrangement of five Transvarcoupled waveguides.

55.3. Effects and Measurement of Harmonics in High Power Waveguide Systems

M. P. Forrer and K. Tomiyasu, *General Electric Microwave Lab., Palo Alto, Calif.*

With increasing power levels of radar systems, the adverse effects due to harmonics of the carrier frequency have become significant. Such harmonic energies can propagate through the waveguide system in many modes. Because of the ambiguous modal distribution of the propagating harmonic energies in a waveguide, the determination of the relative power levels of the propagating modes is an extremely complex problem.

For an arbitrary superposition of propagating modes in a lossless, straight, rectangular

waveguide, a measuring technique has been developed to determine the power of each mode. The procedure employs electric probes, sliding across the waveguide walls at various cross sections. The mathematical formalism linking the measured probe data with the power of each mode is described and a brief description of experimental results is given.

55.4. Microwave Dielectric Properties of Solids for Applications at Temperatures to 3000°F

D. M. Bowie, *Melpar, Inc., Falls Church, Va.*

Measured values of dielectric constant and loss tangent of a number of plastic and ceramic materials at numerous temperatures ranging from room temperature to as high as 3000° F are reported. Tests were made at frequencies of 200 mc and 3000 mc. Refinements in the existing shorted-transmission-line measuring technique have been made in order to provide nearly uniform accuracy over a wide range of temperature.

Materials have been selected for investigation on the basis of their potential utility in high-temperature microwave applications. An extensive investigation is reported on pure materials and mixtures in the form of foams, laminates, and filled bodies, including Teflon, silicone resins, epoxy resins, glasses, and ceramics. The temperature range in every case is extended to 3000°F or to the limit of the material.

Results show generally an increase in both dielectric constant and loss with temperature, except for highly expansive materials, which show a decrease in dielectric constant with temperature. For plastics, temperature limits are indicated above which irreversible changes in dielectric properties occur. Curves of dielectric properties vs time at fixed elevated temperatures are shown for these materials.

55.5. Traveling-Wave Cavity for Ferrite Tensor Permeability Measurements

L. A. Ault, E. G. Spencer, and R. C. LeCraw, *The Diamond Ordnance Fuze Labs., Washington, D. C.*

A waveguide annular ring is described for use in measuring the components of the tensor permeability of ferrites. Unidirectional wave propagation within the ring, together with the resonant properties of the ring, constitute a traveling-wave cavity in a bridge circuit. The ferrite sample, which may be a small rod or thin slab, is placed in the waveguide ring at a position away from the side walls at which the rf fields are circularly polarized. As the applied dc field is varied, the loss and dispersion components of the permeability change, resulting in an unbalanced bridge. The components of permeability are measured by a calibrated phase shifter and a calibrated attenuator in the ring, which are used to rebalance the bridge.

The merits of this new method are evaluated and compared with other cavity perturbation methods for measuring tensor permeability components.

55.6. The Principle of a Non-Gyromagnetic Ferrite Phase-Shifter

S. Wenglin, *New York University, New York, N. Y.*

If a linearly polarized plane electromagnetic wave propagates through an infinite ferromagnetic medium, magnetized parallel to the magnetic component of the wave, the value of the permeability in the propagation constant is the incremental permeability. This incremental permeability, and thus the phase delay, may be varied by varying the magnetic bias. Magnetic properties may be controlled by utilizing a medium consisting of ferrite spheres embedded in a dielectric. Restrictions on the size and distribution of spheres are those usual for the application of the Clausius-Mosotti formula. A more general form of the Clausius-Mosotti formula is derived which relates the B, H values in the mixture to the B, H values in the ferrite spheres.

IRE News and Radio Notes

Eastham Wins Armstrong Medal

Melville Eastham (A'13–M'13–F'25) was recently awarded the Armstrong Medal by the Radio Club of America "in recognition of his outstanding contributions to the art of precision measurements in the radio and electronic field."



M. Eastham

Mr. Eastham, for fifty years a design engineer, was the founder of the General Radio Company, Cambridge, Massachusetts, and its president from 1915 to 1944.

Active in IRE committee work, Mr. Eastham was Treasurer from 1928 to 1940, Manager from 1922 to 1927 and Director from 1927 to 1941. He also served as secretary to the Boston IRE Section, and as IRE representative on other organizations. In 1937 he was awarded the IRE Medal of Honor.

Mr. Eastham also holds membership in the American Association for the Advancement of Science, American Institute of Electrical Engineers, Acoustical Society of America, American Physical Society, and American Meteorological Society.

Chairmen Listed for Seventh Region Meeting at San Diego

The 1957 Seventh IRE Region Conference will be held at San Diego, California, April 24–26. The theme of the conference will be "Electronics in Space."

L. G. Trolese is general chairman of the conference. Assisting him will be Jack Bowers, secretary; Don Root, exhibits; R. T. Silberman, publicity; R. E. Honer, technical program; J. P. Day, finance; L. H. Orpin, entertainment; R. U. F. Hopkins, transportation; Chesney Moe, student program; D. C. Kalbfell, member at large; and San Diego section chairman Robert Kirkman and Al Drayer, secretary.

Over fourteen technical sessions are planned. Session chairmen will be: L. L. Beranek, M.I.T., *Audio-Video;* R. G. Stegen, Canoga Corp., *Microwave;* J. M. Pettit, Stanford Univ., *Wednesday Luncheon;* C. Moe, San Diego State College, *Student Papers;* J. B. Smyth, Smyth Research Associates, *Antennas and Propagation;* L. M. Silva, Beckman Instruments, *Data Handling and Automation;* D. M. Stuart, CAA, Technical Development Center, *Electronic Aids to Air Navigation;* J. E. Keister, General Electric, *Electron Devices;* R. A. Helliwell, Stanford Univ., *International Geophysical Year;* Norman Moore, Litton Industries, *Electron Tubes;* B. S. Billington, Oak Ridge National Laboratory, *Nuclear Activation and Damage;* Martin Klein, Rocketdyne, North American Aviation, *Instrumentation.*

Technical tours and ladies' activities will also be included in the conference schedule.

IRE Adds New Subsection

The IRE Executive Committee, at its meeting on January 3, approved the formation of the Lehigh Valley Subsection of the Philadelphia IRE Section.

On the following day, the name and status of the Centre County Subsection were changed to the Central Pennsylvania Section.

Southwestern and Simulation Conferences to Hold Simultaneous Sessions April 10–13

The Ninth Annual Southwestern IRE Conference and Show, sponsored by the Houston IRE Section, and the Second National Simulation Conference, sponsored by the IRE Professional Group on Electronic Computers, will be held at the Shamrock-Hilton Hotel, Houston, Texas, April 10–13. Five technical sessions of both conferences will be held simultaneously.

Exhibits for both conferences will open April 11, and close on the 14th. The registration desk, however, will be ready for visitors from 2 to 10 p.m. on the 10th so that arrangements for technical tours and a ladies' program can be made early.

Instrumentation and geophysics will be discussed during the technical sessions of the Southwestern Conference on April 11; computer devices and physical simulation, during the Simulation Conference sessions on that day. On the following day, technical sessions of the Southwestern Conference will be on communications and medical electronics; the Simulation Conference will discuss function generators and physical simulation. On the 13th, the Southwestern Conference will hold a session on industrial applications of electronics, and simultaneously the Simulation Conference will discuss special applications of simulation techniques.

Four events mark the social calendar of both conferences. Since the National IRE Board of Directors will hold their April meeting in Houston at this time, there will be a luncheon in their honor on the 11th, and on the evening of the following day a reception will also be held. Following the reception there will be a buffet dinner and an aquacade.

A luncheon on the 12th will feature a speech by J. A. Van Allen, professor of physics at Iowa University and U.S.—I. G. Y. Committee member, on the latest developments in the earth satellite program and its part in the International Geophysical Year.

Harvey Wheeler of KPRC-TV is chairman of the bi-conference committee. Committee members are: R. L. Ransome, Section Chairman; W. J. Greer, Vice-Chairman and Special Guests; P. E. Franklin, Business Manager and Housing; L. H. Gollwitzer, Secretary and Registration; F. C. Smith, Jr., Program; K. O. Heintz, Exhibits; J. K. Hallenburg, Tours and Banquet; R. A. Arnett, Technical Chairman; E. F. Neuenschwander, Arrangements; M. A. Arthur, Publicity; and Mrs. K. H. Woehst, Ladies.

Calendar of Coming Events

National Biophysics Conference, Columbus, Ohio, March 4–6

EJC Second Annual Nuclear Science and Engineering Congress, Convention Hall, Philadelphia, Pa., March 11–14

IRE National Convention, Waldorf-Astoria and New York Coliseum, New York City, March 18–21

Colloquium on Radiation Effects, Shriver Hall, Johns Hopkins University, Baltimore, Md., March 27–29

British Radio & Electronic Component Show, Grosvenor House and Park Lane House, London, England, Apr. 8–11

Industrial Electronics Conference, Ill., Inst. of Tech., Chicago, Ill., April 9–10

First National Nuclear Instrumentation Conference, Atlanta, Ga., Apr. 10–12

Ninth Southwestern Regional Conference & Show, Shamrock-Hilton Hotel, Houston, Tex., April 11–13

National Simulation Conference, Shamrock-Hilton Hotel, Houston, Tex., April 11–13

PGTRC National Telemetering Symposium, Philadelphia, Pa., April 14–16

Annual Engineering Convention and Exhibition of the IRE Buenos Aires Section, Buenos Aires, Argentina, April 22–28

Symposium on Role of Solid State Devices in Electric Circuits. Engrg. Society Bldg., New York City, April 23–25

Region Seven Technical Conference & Trade Show, San Diego, Calif., April 24–26

Eleventh Annual Spring Television Conference, Engrg. Society Bldg., Cincinnati, Ohio, April 26–27

Electronic Components Conference, Morrison Hotel, Chicago, Ill., May 1–3

Symposium on Microwave Ferrites and Devices & Applications, Western Union Auditorium, New York City, May 9–10

National Aero. and Nav. Electronics Conference, Dayton, Ohio, May 13–15

Fifth Annual Semiconductor Symposium of the Electrochemical Society, Statler Hotel, New York City, May 13–16

PGPT First Annual Conference on Production Techniques, Willard Hotel, Washington, D. C., June 6–7

PGMIL First National Meeting, Sheraton-Park Hotel, Washington, D. C., June 17–19

International Symposium on Physical Problems of Color Television. Paris France, July 2–6

WESCON, Fairmont Hotel and Cow Palace, San Francisco, Calif., Aug. 20–23

URSI Twelfth General Assembly. Boulder, Colo., Aug. 22–Sept. 5

Special Technical Conference on Magnetic Amplifiers, Penn Sheraton Hotel, Pittsburgh, Pa., Sept. 4–6

Industrial Electronics Symposium, Morrison Hotel, Chicago, Ill., Sept. 24–25

Three-Day EJC Conference Revealed New Developments

The three-day 1956 Eastern Joint Computer Conference & Exhibition opened at New York City's Hotel New Yorker and Manhattan Center, December 10, 1956. This sixth annual meeting, jointly sponsored by the IRE, American Institute of Electrical Engineers and Association for Computing Machinery, focused attention on the theme "New Developments in Computers."

A record registration of several thousand electronic engineers and business executives viewed the equipment displays of more than thirty leading manufacturers and research laboratories in the computer field. The keynote address was made by H. T. Engstrom of the National Security Agency. During the conference technical papers discussing various aspects of computer systems, components, circuits, input-output devices and high-speed memories were presented by twenty-nine authorities in the field.

As a permanent record of this exchange of information, each conference registrant received a free copy of the conference proceedings, which included a complete text of all technical papers presented at the conference.

Johns Hopkins Univ. Holds March Colloquium on Radiation

The Office of Naval Research, Navy Department, and the Glenn L. Martin Company will co-sponsor a colloquium on radiation effects on materials to be held on the campus of Johns Hopkins University at Shriver Hall, Baltimore, Md., March 27–29.

The colloquium is planned for the presentation of unclassified educational review papers on the subject of radiation effects on materials. The program has been designed to appeal to the engineer and the research scientist interested in radiation effects, and the development and application of nuclear reactors for power. Approximately one hour will be allowed for each paper's presentation and ample time will be available for discussion from the floor.

The first day's program will consist of papers on defects in solids and current concepts of radiation effects, experimental approaches to radiation studies, radiation sources and dosimetry, radiation effects on physical and metallurgical properties of metals and alloys, influence of radiation upon corrosion behavior, and surface properties of metals and alloys.

Topics to be discussed on the second day of the colloquium will be effects of radiation on electronic and optical properties of inorganic dielectric materials, effects of radiation on semiconductors, and effects of radiation on organic materials. On the last day of the colloquium, papers will be presented on the effects of radiation on reactor components. A round table, open forum discussion will then follow.

Further information may be obtained from: J. G. Morse, Supervisor, Radiation Effects Unit, Nuclear Division, Mail 711, Glenn L. Martin Co., Baltimore 3, Md., and J. J. Harwood, Head, Metallurgy Branch, Office of Naval Research, Navy Department, Washington 25, D. C.

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Aeronautical & Navigational Electronics	PGAE-5 (6 pages)	$ .30	$ .45	$ .90
	PGAE-6 (10 pages)	.30	.45	.90
	PGAE-8, June 1953 (23 pages)	.65	.95	1.95
	PGAE-9, September 1953 (27 pages)	.70	1.05	2.10
	Vol. ANE-1, No. 2, June 1954 (22 pages)	.95	1.40	2.85
	Vol. ANE-1, No. 3, September 1954 (27 pages)	1.00	1.50	3.00
	Vol. ANE-1, No. 4, December 1954 (27 pages)	1.00	1.50	3.00
	Vol. ANE-2, No. 1, March 1955 (41 pages)	1.40	2.10	4.20
	Vol. ANE-2, No. 2, June 1955 (49 pages)	1.55	2.30	4.65
	Vol. ANE-2, No. 3, September 1955 (27 pages)	.95	1.45	2.85
	Vol. ANE-2, No. 4, December 1955 (47 pages)	1.40	2.10	4.20
	Vol. ANE-3, No. 1, March 1956 (42 pages)	1.30	1.95	3.90
	Vol. ANE-3, No. 2, June 1956 (54 pages)	1.40	2.10	4.20
	Vol. ANE-3, No. 3, September 1956 (39 pages)	1.05	1.55	3.15
	Vol. ANE-3, No. 4, December 1956 (36 pages)	.85	1.25	2.55
Antennas and Propagation	Vol. AP-1, No. 1, July 1953 (30 pages)	1.20	1.80	3.60
	Vol. AP-1, No. 2, October 1953 (31 pages)	1.20	1.80	3.60
	Vol. AP-2, No. 1, January 1954 (39 pages)	1.35	2.00	4.05
	Vol. AP-2, No. 2, April 1954 (41 pages)	2.00	3.00	6.00
	Vol. AP-2, No. 3, July 1954 (36 pages)	1.50	2.25	4.50
	Vol. AP-3, No. 4, October 1954 (36 pages)	1.50	2.25	4.50
	Vol. AP-3, No. 1, January 1955 (43 pages)	1.60	2.40	4.80
	Vol. AP-3, No. 2, April 1955 (47 pages)	1.60	2.40	4.80
	Vol. AP-4, No. 1, January 1956 (100 pages)	2.65	3.95	7.95
Audio	PGA-7 (47 pages)	.90	1.35	2.70
	PGA-10, November–December 1952 (27 pages)	.70	1.05	2.10
	Vol. AU-1, No. 2, March–April 1953 (34 pages)	.80	1.20	2.40
	Vol. AU-1, No. 6, November–December 1953 (27 pages)	.90	1.35	2.70
	Vol. AU-2, No. 1, January–February 1954 (38 pages)	1.20	1.80	3.60
	Vol. AU-2, No. 2, March–April 1954 (31 pages)	.95	1.40	2.85
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	Vol. AU-2, No. 4, July–August 1954 (27 pages)	.95	1.40	2.85
	Vol. AU-2, No. 5, September–October 1954 (22 pages)	.95	1.40	2.85
	Vol. AU-2, No. 6, November–December 1954 (24 pages)	.80	1.20	2.40
	Vol. AU-3, No. 1, January–February 1955 (20 pages)	.60	.90	1.80
	Vol. AU-3, No. 2, March–April 1955 (32 pages)	.95	1.40	2.85
	Vol. AU-3, No. 3, May–June 1955 (30 pages)	.85	1.25	2.55
	Vol. AU-3, No. 5, September–October 1955 (33 pages)	.90	1.35	2.70
	Vol. AU-3, No. 6, November–December 1955 (36 pages)	.95	1.40	2.85
	Vol. AU-4, No. 1 January–February 1956 (27 pages)	.75	1.10	2.25
	Vol. AU-4, No. 2, March–April 1956 (17 pages)	.55	.80	1.65
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	Vol. AU-4, No. 4, July–August 1956 (23 pages)	.60	.90	1.80
	Vol. AU-4, No. 5, September–October 1956 (31 pages)	.60	.90	1.80
Automatic Control	PGAC-1, May 1956 (97 pages)	1.95	2.90	5.85
Broadcast Transmission Systems	PGBTS-2, December 1955 (54 pages)	1.20	1.80	3.60
	PGBTS-4, March 1956 (21 pages)	.75	1.10	2.25
	PGBTS-5, September 1956 (51 pages)	1.05	1.55	3.15
	PGBTS-6: October 1956 (32 pages)	.80	1.20	2.40
Broadcast and Television Receivers	PGBTR-1: (12 pages)	.50	.75	1.50
	PGBTR-5: January 1954 (96 pages)	1.80	2.70	5.40
	PGBTR-7: July 1954 (58 pages)	1.15	1.70	3.45
	PGBTR-8: October 1954 (20 pages)	.90	1.35	2.70
	Vol. BTR-1, No. 1, January 1955 (68 pages)	1.25	1.85	3.75
	Vol. BTR-1, No. 2, April 1955 (40 pages)	.95	1.45	2.85
	Vol. BTR-1, No. 3, July 1955 (51 pages)	.95	1.45	2.85
	Vol. BTR-1, No. 4, October 1955 (19 pages)	.95	1.40	2.85
	Vol. BTR-1, No. 1, April 1956 (30 pages)	1.10	1.65	3.30
	Vol. BTR-2, No. 2, July 1956 (21 pages)	.85	1.25	2.55
	Vol. BTR-2, No. 3, October 1956 (32 pages)	1.05	1.55	3.15

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	Vol. CT-3, No. 2, June 1956 (74 pages)	1.60	2.40	4.80
	Vol. CT-3, No. 3, September 1956 (44 pages)	1.00	1.50	3.00
Communications Systems	Vol. CS-2, No. 1, January 1954 (83 pages)	1.65	2.50	4.95
	Vol. CS-2, No. 2, July 1954 (132 pages)	2.25	3.35	6.75
	Vol. CS-2, No. 3, November 1954 (181 pages)	3.00	4.50	9.00
	Vol. CS-3, No. 1, March 1955 (72 pages)	1.00	1.50	3.00
	Vol. CS-4, No. 2, May 1956 (182 pages)	2.90	4.35	8.70
	Vol. CS-4, No. 3, October 1956 (59 pages)	1.05	1.55	3.15
Component Parts	PGCP-1: March 1954 (46 pages)	1.20	1.80	3.60
	PGCP-2: September 1954 (119 pages)	2.25	3.35	6.75
	PGCP-3: April 1955 (44 pages)	1.00	1.50	3.00
	Vol. CP-3, No. 1, March 1956 (35 pages)	1.70	2.55	5.10
	Vol. CP-3, No. 2, September 1956 (44 pages)	1.75	2.60	5.25
Electronic Computers	Vol. EC-3, No. 3, September 1954 (54 pages)	1.80	2.70	5.40
	Vol. EC-4, No. 4, December 1955 (40 pages)	.90	1.35	2.70
	Vol. EC-5, No. 2, June 1956 (46 pages)	.90	1.35	2.70
	Vol. EC-5, No. 3, September 1956 (72 pages)	1.05	1.55	3.15
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	Vol. ED-1, No. 3, August 1954 (77 pages)	1.40	2.10	4.20
	Vol. ED-1, No. 4, December 1954 (280 pages)	3.20	4.80	9.60
	Vol. ED-2, No. 2, April 1955 (53 pages)	2.10	3.15	6.30
	Vol. ED-2, No. 3, July 1955 (27 pages)	1.10	1.65	3.30
	Vol. ED-2, No. 4, October 1955 (42 pages)	1.50	2.25	4.50
	Vol. ED-3, No. 1, January 1956 (74 pages)	2.10	3.15	6.30
	Vol. ED-3, No. 2, April 1956 (40 pages)	1.10	1.65	3.30
	Vol. ED-3, No. 3, July 1956 (45 pages)	1.35	2.00	4.05
	Vol. ED-3, No. 4, October 1956 (48 pages)	1.45	2.15	4.35
Engineering Management	PGEM-1: February 1954 (55 pages)	1.15	1.70	3.45
	Vol. EM-3, No. 1, January 1956 (29 pages)	.95	1.40	2.85
	Vol. EM-3, No. 2, April 1956 (15 pages)	.55	.80	1.65
	Vol. EM-3, No. 3, July 1956 (37 pages)	.90	1.35	2.70
Industrial Electronics	PGIE-1: August 1953 (40 pages)	1.00	1.50	3.00
	PGIE-2: March 1955 (81 pages)	1.90	2.85	5.70
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Information Theory	PGIT-3: March 1954 (159 pages)	2.60	3.90	7.80
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	Vol. MTT-4, No. 4, October 1956 (84 pages)	1.85	2.75	5.55
Nuclear Science	Vol. NS-1, No. 1, September 1954 (42 pages)	.70	1.00	2.00
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	Vol. NS-3, No. 1, February 1956 (40 pages)	.90	1.35	2.70
	Vol NS-3, No. 2, March 1956 (31 pages)	1.40	2.10	4.20
	Vol. NS-3, No. 3, June 1956 (24 pages)	1.00	1.50	3.00
	Vol. NS-3, No. 4, November 1956 (144 pages)	4.50	6.75	13.50

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Wescon Papers Deadline Set for May 1

Authors wishing to present papers at the 1957 WESCON Convention to be held in San Francisco on August 20–23 should send 100–200-word abstracts, together with complete texts or additional detailed summaries, to the Technical Program Chairman, D. A. Watkins, Stanford Electronics Laboratories, Stanford University, Stanford, California, by May 1, for consideration by the Technical Program Committee. Authors will be notified whether or not their papers have been accepted by June 1.

USA-URSI Meets May 22–25

The USA National Committee of URSI has scheduled its spring meeting for May 22–25 at Hotel Willard, Washington, D. C. Co-sponsors of the meeting will be the IRE PGAP, PGCT, PGI, PGIT, and PGMTT.

A general session will be held for all participants on the morning of May 23, followed by one or more sessions in each of these fields: Commission 1—Radio Measurements and Standards; Commission 2—Radio and Troposphere; Commission 3—Ionospheric Radio; Commission 4—Radio Noise of Terrestrial Origin; Commission 5—Radio Astronomy; Commission 6—Radio Waves and Circuits; and Commission 7—Radio Electronics.

Authors should submit titles and 100–200-word abstracts of their proffered papers on or before March 15. Papers should be sent to the appropriate person chosen from the following: Commission 1—E. Weber, Polytechnic Institute of Brooklyn, 99 Livingston St., Brooklyn, N. Y.; Commission 2—J. B. Smyth, Smyth Research Associates, 3930 Fourth Ave., San Diego 3, Calif.; Commission 3—L. A. Manning, Dept. of Elec. Eng., Stanford University, Stanford, Calif.; Commission 4—A. W. Sullivan, Engineering and Industrial Experimental Station, Univ. of Florida, Gainesville, Fla.; Commission 5—F. T. Haddock, Observatory, Univ. of Michigan, Ann Arbor, Mich.; Commission 6—E. C. Jordan, Dept. of Elec. Eng., Univ. of Illinois, Urbana, Ill.; Commission 7—W. G. Shepherd, Dept. of Elec. Eng., Phillips Hall, Cornell University, Ithaca, N. Y.; PGAP—H. G. Booker, School of Elec. Eng., Phillips Hall, Cornell University, Ithaca, N. Y.; or PGMTT—F. G. Marble, Boonton Radio Corp., Intervale Road, Boonton, N. J.

First Fall NEREM Hears Sixteen Technical Papers

The New England Radio-Electronics Meeting, held for the first time in the fall, took place at the Hotel Bradford, Boston, Massachusetts, November 15–16. Nearly fifteen hundred persons attended the meeting, which was sponsored by the Boston and Connecticut Valley IRE Sections.

The following papers were presented at the meeting: *The Information Theory Outlook on Communication Systems of the Future,*

R. M. Fano; *Communications—A Look Ahead*, E. I. Green; *Exploitation of the Tropospheric Propagation Mode—Present and Future*, C. L. Mack, Jr.; *Company Standards Programs in the Electronics Industry*, R. G. Munroe; *The Science of Value Analysis*, L. D. Miles; *The Potentialities of Long Range Radio Aids to Navigation*, J. A. Pierce; and *Altimeters*, F. T. Wimberly.

Also *Electronic Analog Computers*, J. M. Embree; *Automation—Its Impact on Management*, C. W. Boyce; *The Problem of the Creative Engineer*, C. D. Orth, 3rd; *Present and Future Network Synthesis*, E. A. Guillemin; *Applied Circuit Theory*, W. N. Tuttle; *Nonlinear Circuitry*, Ernst Weber; *Perception and Pattern Recognition in Automata*, O. G. Selfridge; *Characteristics of Manual Control Systems*, J. I. Elkind; and *The Role of Men in Automation Systems*, B. F. Green, Jr.

E. F. Carter, Director of the Stanford Research Institute at Palo Alto, Calif., and the dinner speaker, discussed "Idea Acceleration."

Information Available for April Television Conference

The Eleventh Annual Spring Technical Conference on Television will be held this year at the Engineering Society Building in Cincinnati, Ohio, April 26–27. This conference will be sponsored by the Cincinnati IRE Section in cooperation with the IRE Professional Groups on Broadcast and Television Receivers, and Broadcast Transmission Systems.

A. T. Bolt, Jr. and V. J. Scott are co-chairmen of the conference, and J. R. Ebbeler of Avco Manufacturing Corporation is papers chairman.

Information concerning advance registration or hotel reservations can be obtained from C. B. Shaw, Jr., Hangar Three, Lunken Airport, Cincinnati 6, Ohio. Advertising and exhibition privileges can be obtained upon request from J. R. Ragen, 3825 Mantell Ave., Cincinnati 36, Ohio.

PGEC Sponsors Fellowship

During the past two years, negotiations were completed which presently enable the PGEC to sponsor an annual Fellowship for graduate study in computing. The amount of the stipend is $2,000, plus tuition not to exceed $1,000. Initially this Fellowship is underwritten by the PGEC for two years, although it is hoped that it can be supported on a continuing basis.

This Fellowship is administered through the Office of Scientific Personnel of the National Academy of Sciences, and the selection of the successful recipient is made by that office. The first Fellowship has already been awarded for the 1957–58 academic year. There are no restrictions as to the university or college to be attended, but it is necessary for the Fellow to specialize in computing or a closely allied field.

Applications for this Fellowship should be addressed to: Fellowship Office, Office of Scientific Personnel, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington 25, D. C.

AVAILABLE BACK COPIES OF IRE TRANSACTIONS

(Continued)

Sponsoring Group	Publications	Group Members	IRE Members	Non-Members*
Production Techniques	PGPT-1: September 1956 (57 pages)	$1.20	$1.80	$3.60
Reliability and Quality Control	PGQC-2: March 1953 (51 pages)	1.30	1.95	3.90
	PGQC-3: February 1954 (39 pages)	1.15	1.70	3.45
	PGQC-4: December 1954 (56 pages)	1.20	1.80	3.60
	PGRQC-5: April 1955 (56 pages)	1.15	1.75	3.45
	PGRQC-6: February 1956 (66 pages)	1.50	2.25	4.50
	PGRQC-7: April 1956 (52 pages)	1.10	1.65	3.30
	PGRQC-8: September 1956 (58 pages)	1.10	1.65	3.30
Telemetry and Remote Control	PGRTRC-1: August 1954 (16 pages)	.85	1.25	2.55
	PGRTRC-2: November 1954 (24 pages)	.95	1.40	2.85
	Vol. TRC-1, No. 1, February 1955 (24 pages)	.95	1.40	2.85
	Vol. TRC-1, No. 2, May 1955 (24 pages)	.95	1.40	2.85
	Vol. TRC-1, No. 3, August 1955 (12 pages)	.70	1.05	2.10
	Vol. TRC-2, No. 1, March 1956 (22 pages)	1.00	1.50	3.00
Ultrasonics Engineering	PGUE-1: June 1954 (62 pages)	1.55	2.30	4.65
	PGUE-4: August 1956 (75 pages)	1.50	2.25	4.50
Vehicular Communications	PGVC-5: June 1955 (78 pages)	1.50	2.25	4.50
	PGVC-6: July 1956 (82 pages)	1.55	2.30	4.65
	PGVC-7: December 1956 (53 pages)	1.20	1.80	3.60

* Public libraries, colleges and subscription agencies may purchase at IRE member rate.

PGMTT Holds Meeting May 9-10

The annual meeting of the IRE Professional Group on Microwave Theory and Techniques will take place at Western Union Auditorium, New York City, May 9–10. The program will emphasize reports on advances in microwave ferrite devices and their applications, non-reciprocal propagation in gas media, and microwave solid-state devices. Invited speakers include Benjamin Lax of M.I.T.'s Lincoln Laboratory who will discuss microwave properties and investigations of semiconductors, Louis Goldstein of the University of Illinois whose topic will be "Non-Reciprocal Electromagnetic Wave Propagation in Ionized Gaseous Media," and H. E. D. Scovil of Bell Telephone Labs who will present a new approach to a solid-state microwave amplifier in his talk "Solid State MASER."

There will be two sessions of contributed papers, abstracts for which are due March 1. Authors should send 200-word abstracts to Sam Weisbaum, Technical Program Chairman, Bell Telephone Labs., Murray Hill, N. J.

The last session of the meeting will be devoted to a round-table discussion on design limitations of microwave ferrite devices and cover high power effects, low frequency limits, high frequency limits, anomalous propagation in ferrite loaded waveguides, below saturation behavior of ferrites, "fast" ferrite devices (depending upon relaxation time), bandwidth problems, and material losses. The discussion will be led by the following panelists: H. Seidel, Bell Tel. Labs.; G. S. Heller, M.I.T. Lincoln Lab.; R. C. LeCraw, Diamond Ordnance Fuse Labs.; J. O. Artman, Harvard University; P. H. Vartanian, Sylvania; H. Carlin, Microwave Research Institute; and D. L. Fresch, Trans-Tech, Inc.

The annual award for the best paper appearing in the Transactions of PGMTT will be presented at a dinner scheduled for the evening of May 9.

Technical Committee Notes

Chairman P. A. Redhead presided at a meeting of the **Electron Tubes** Committee held at IRE Headquarters on January 11. The committee reviewed the Proposed Standard on Testing of Storage Cathode-Ray Tubes. This is one section of the Proposed Standard on Electron Tubes: Methods of Test which the committee is now preparing.

The **Nuclear Techniques** Committee met at the National Bureau of Standards in Washington, D. C. on December 18 with Chairman G. A. Morton presiding. The entire meeting was devoted to the review of the Proposed Standard on Definitions of Terms, which is presently in preparation in the committee.

Chairman M. W. Baldwin presided at a meeting of the **Standards** Committee held at IRE Headquarters on January 10.

The Proposed Standard on Electron Tubes: Noise Definitions was discussed, amended and unanimously approved for publication as an IRE Standard.

Consideration of the revisions in the Standards on Gas-Filled Radiation-Counter Tubes: Definitions of Terms, 1952 was postponed at the request of G. A. Morton, Chairman of the Nuclear Techniques Committee. Dr. Morton wishes to have his committee review the Standard before it is approved by the Standards Committee.

Review of the Proposed Standard on Navigation Aids: Direction Finder Measurements was started, and will continue at the next meeting of the committee.

Books

Engineering Mathematics by K. S. Miller

Published (1956) by Rinehart & Co., 232 Madison Ave., N. Y. 16, N. Y. 408 pages+8 index pages+xiii pages. Illus. 9×6. $6.50.

There are many text books on the subject of advanced mathematics for engineers and/or physicists and more are coming out every year. A new addition to this field which should prove quite valuable to a senior undergraduate or first-year graduate curriculum on communications engineering is the subject book listed above.

This book contains many of the topics often included in similar books. These topics include determinants and matricies, special integrals such as the gamma function, beta function, error function, elliptic integrals and so on, linear differential equations including solutions in series and the well-known equations of Legendre, Hermite and Bessel, Fourier series and integrals and the La Place transformations. In addition, there is a chapter on network theory and, even more important, a very well-written chapter on random functions which is a very vital subject to modern communication theory.

Since the book is apparently restricted to use in an electrical engineering curriculum, it does not include any topics which might be considered of greater interest to the physicist such as heat flow problems, vibrating strings and plates, or hanging cables. Although it is doubtful if everything that is included in the book could be covered in a one-year course, still it is felt that there are two important topics that should have been included to make it a more complete and useful reference book to a graduate student of electrical engineering; namely, complex variable theory, especially integration in the complex plane and electromagnetic theory, and fields and waves in transmission lines and waveguides.

It is to be particularly noted that no mathematical topic is introduced merely to exhibit mathematical gymnastics; instead, new mathematical techniques and methods are introduced in conjunction with the solutions to interesting and useful physical problems. It is this approach which makes it of particular interest to this reviewer.

HAROLD STARAS
RCA Laboratories
Princeton, N. J.

Mechanical Design for Electronics Production by J. M. Carroll

Published (1956) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 334 pages+9 index pages+1 page of bibliography+iii pages. Illus. 9×6. $6.50.

As mentioned in the preface, the volume is intended primarily for the working engineer. The book serves as an introduction, due to its comprehensive coverage, to bring awareness of the many important factors related to product design and production techniques providing much needed reliability and reduction of costs. A listing of the chapter titles may serve to indicate the subjects discussed—Chapter 1, The Importance of Mechanical Design; Chapter 2, Space Planning in Equipment Design; Chapter 3, Chassis Design and Layout; Chapter 4, Fabricating the Chassis; Chapter 5, Manufacturing Small Parts; Chapter 6, Shielding Components and Equipment; Chapter 7, Potting, Embedding and Encapsulating; Chapter 8, Moving Parts; Chapter 9, Electric Motors and Rotating Components; Chapter 10, Wiring and Soldering; Chapter 11, Assembly Methods; Chapter 12, Cabinet Construction; and Chapter 13, Environmental Factors in Equipment Design.

Chapters 1, 2, 8, 10 and 12 contain a wealth of information which should be of interest to each electronics, mechanical and production engineer. Chapter 7 on potting is a good introduction to a subject all too often unfamiliar to the product designer who lacks knowledge of plastic materials and processing techniques. It was a bit disappointing to find that the very important subject of protective coatings was not discussed more thoroughly. Chapter 11 which gives a comparison of three well known in-line assembly machines, is quite useful. With the growing interest in reliability and ruggedization, Chapter 13 did not quite give sufficient emphasis to the importance of environmental testing and its influence on mechanical design of equipment. This chapter would have been considerably strengthened had it contained a discussion of component and sub-assembly mounting to withstand environmental stresses. The subject of cooling, very important when miniaturization is considered and with electronic systems becoming more and more complex, deserves more treatment. The bibliography, although good, should be expanded to provide adequate references to all the subjects discussed.

All in all, though, the book serves a useful purpose by supplying sufficient detail to be of some aid to the design engineer.

L. K. LEE
Ramo-Wooldridge Corporation
Los Angeles 45, California

Électricité, 6th ed., by G. Goudet

Published (1956) by Masson et Cie, 120, Boulevard Saint-Germain, Paris 6, France. 900 pages+4 index pages+1 appendix page+3 pages of bibliography. 517 figures. 9¼×6¾. 4.500 F., paper; 5.100 F., cloth.

This treatise on the theory of electricity is a revised edition of a part of the well-known course of G. Bruhat dealing with general physics. Bruhat's work has long been considered in France as a classic for undergraduate and postgraduate students in French universities, as well as more generally for engineers and research men in quest of a reliable review of up-to-date fundamentals in this field. The author died during World War II, a victim of his sense of duty toward profession and country. Professor Goudet has been entrusted with the difficult task of revising this outstanding book. No better choice could have been made. Dr. Goudet has done the job with a feeling of devoted gratitude toward his former professor, as well as with utmost competence.

The book had been written with the characteristic clarity and logic often associated with the scientific teachings of outstanding French professors. However, it was in need of substantial revision because of the rapid evolution of thought and knowledge after the end of the last World War. An instance of the decisions which Professor Goudet had to make is the choice between the initial parallelism of magnetic and electric point masses as usually utilized before the war in French universities, and the derivation of magnetic properties of matter from electric currents, leaving the concept of magnetic mass as a pure mathematical tool with no physical support as is generally preferred in today's scientific circles. Prof. Goudet has introduced the latter view in the book, and proceeded very methodically from the static phenemena of both electric and magnetic nature, through quasi-stationary problems, to crown the whole electromagnetic theory with Maxwell's equations, which he has explained carefully by means of a number of applications amply demonstrating their practical usefulness as well as their profound content. A chapter follows on the Lorentz' transformation and the relativity theory.

Though the modern ideas about the way matter is constituted are explained and alluded to in the first part of the book, it is in the latter chapters that microscopic phenomena are more specifically considered. The chapter on electrons and the examination of their properties in accordance with classical, relativistic and wave mechanics is an excellent introduction to modern concepts of which the author has explained the general laws in succeeding chapters dealing with various particle constituents of atoms and molecules. The book closes with a clear, though brief review of the basic properties of solid state physics and vacuum tubes.

The Giorgi system of rationalized units has been consistently utilized throughout the book The bibliography is deliberately limited to classical publications, with preponderant references to French works.

This reviewer had the occasion to discuss a few points with the author about his revision, and is fully aware of the thoroughly competent and painstaking work which Prof. Goudet has done to bring up-to-date a treatise of such repute and quality. This book is unreservedly recommended to all radio engineers for its clarity, precision and care in establishing definitions of concepts and demonstrations of properties.

A. G. CLAVIER
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Nutley, N. J.

Electronic Analog Computers, 2nd ed., by G. A. Korn and T. M. Korn

Published (1956) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 425 pages+11 index pages+10 pages of bibliography+xiv pages. Illus. 9¼×6½. $7.50.

This second edition reflects recent developments in the rapidly changing field of analog computers. For an adequate understanding of the material, a knowledge of elementary electronics, elementary feedback theory, and mathematics through elementary differential equations is required.

In Chapter 1 a brief introductory discussion to the field is presented. Computer representations of mathematical equations are touched upon, and the errors inherent in such representations are discussed.

Chapter Two is devoted to some of the detailed problems relating to machine set up procedure. Time and amplitude scale factors, machine equations, and block diagrams are discussed. Methods and examples for the solution of constant and variable coefficient linear ordinary differential equations, nonlinear ordinary differential equations, and linear simultaneous equations are presented.

The next chapter is devoted to the illustration of the application of dc analog computers to some representative practical problems. During the presentation of these examples numerous practical and valuable techniques in machine solution are discussed. A fair amount of detail is devoted to the application of dc analog computers to the design and testing of automatic pilots. This chapter closes with a fairly comprehensive listing of dc analog computer applications.

The fourth chapter discusses the theory and design of linear computing elements. Such matters as potentiometer construction and loading corrections are presented. Operational amplifier error analysis, integrator performance, some electronic integrators, error analysis of a dc integrator, and regenerative operational amplifiers are then discussed in subsequent sections. Errors in the solution of linear homogeneous differential equations with constant coefficient due to the limitations of integrators and summing amplifiers are discussed.

Chapter Five is devoted to a fairly detailed discussion pertaining to dc amplifier design including the matter of chopper stabilization. Many practical examples of computer amplifier design are illustrated, and numerous useful hints and suggestions, the results of years of experience by many workers in the field, are presented.

The following chapter is devoted to the theory and design of the nonlinear components of dc analog computers, viz., multipliers and function generators. Here again numerous practical examples of circuits of such devices are presented.

Chapter Seven discusses auxiliary circuits and computer operation. Typical control circuits for carrying out such operations as stand by, reset, compute, hold, etc., are presented. Examples of recording equipment are discussed. Computer power supplies and their design are then treated. The chapter closes with a discussion of some automatic computer features.

The final chapter discusses the design of complete dc analog computer installations and presents a few of the salient features of some of the commercially available equipment.

Among the advances covered in this second edition are late chopper and commutator stabilized dc amplifiers; photoelectric chopper circuits; fm-am multipliers and time division multipliers; design of precision electronic switches; the representation of constraints; the representation of time delays; sampled data control systems; modern simulation techniques applicable to nonlinear servos and process control systems; heat transfer multiplifiers; amplitude selection multipliers; some of the more recent diode function generator circuits; and automatic programming and checking features.

The second edition of this book contains a wealth of material on actual computer circuits, techniques and applications. Therefore, in the opinion of the reviewer, this book is a must for those who are or expect to be connected with this field.

C. T. LEONDES
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Radio Telemetry, 2nd ed., by M. H. Nichols and L. L. Rauch

Published (1956) by John Wiley and Sons, Inc. 440 Fourth Ave., N. Y. 16, N. Y. 361 pages+5 index pages+9 pages of bibliography+77 appendix pages +xiii pages. Illus. 9¼×6¼. $12.00.

This book presents an excellent comprehensive coverage of the subject, and in fact, is the first time such a work has been generally available. The first edition had received limited distribution in a paperbound form sponsored by the U. S. Air Force. This second edition includes many revisions and amplifications based on experience gained from the first edition.

There are four parts to the book, each complete in itself and capable of being published separately. Part One is the largest. Entitled "Methods," it describes telemetering from a functional point of view. The treatment is well organized and quite complete, starting with an historical statement of the problem and the need. It gives a general discussion of various methods of solution, a discussion of sources of error and the effect of noise, and points out how this is related to communications. It continues with a discussion of multiplexing methods which is particularly well done. A discussion of the meaning of the received signals for data interpretation follows, after which radio links are discussed together with a comparison of various multiplexing methods. Part One is concluded with a chapter on types of instrumentation for pickups.

Part Two is quite brief, consisting of thirty-three pages. The authors have presented some of the more theoretical aspects of telemetering here in a concise and interesting form. The discussions of modulation and multiplexing, from the mathematical point of view, are here for those interested in the more theoretical details. The authors make no attempt to duplicate basic fundamentals available elsewhere in the literature, but rather approach some of the fundamentals from the point of view of the telemetering problem.

Part Three is devoted to a discussion of telemetering equipment. It describes the currently available equipment to perform the functions described in Part One. The coverage is representative and the examples are well selected. It is not intended to be a complete catalogue. Circuit diagrams are included and discussed along with some very good illustrations and performance records. A brief discussion of data reduction problems and equipment is included along with some comments on remote control command links.

Part Four is a comprehensive set of fourteen appendices. Specific problems are covered here with an analysis of their solutions such as: selection of sub-carrier frequencies in an fm-am system. The RDB Standards and the newer IRIG Standards for radio telemetry are also printed in their entirety in the appendix.

A comprehensive bibliography, glossary and index complete the book. Throughout the text there are many references to the excellent bibliography for those interested in greater detail on any particular subject. The illustrations are exceptionally well done, clear, and concise, and the material is very well organized. The authors have succeeded in arranging the material in increasing order of detail so that it makes an excellent reference.

The book will be useful to those working in the telemetering or remote control fields, whether engaged in the development and design of new and improved equipment or interested in the application of telemetering equipment to a particular problem. While the book is written primarily on the graduate level, it is sufficiently thorough to be of interest and use to the undergraduate.

C. H. DOERSAM, JR.
Fairchild Camera and Instrument Co.
Hicksville, New York

Frequency Modulation Engineering, 2nd rev. ed., by C. E. Tibbs and G. G. Johnstone

Published (1956) by John Wiley & Sons, Inc., 44 Fourth Ave., N. Y. 16, N. Y. 432 pages+3 index pages+xii pages. Illus. 8½×6. $8.50.

The first edition of this authoritative textbook was written by Tibbs alone and was published in 1947. Revisions to bring the book up to date are largely the work of the present co-author. These changes have made the book forty per cent longer and the treatment has been altered substantially. The enlarged edition reflects the latest advances associated with frequency modulation engineering and takes into account recent additions to the literature.

Chapter headings are: 1. Introduction; 2. Frequency Modulation of a Carrier Wave; 3. Interference and Noise Structure; 4. Interference Suppression; 5. Frequency Modulation Propagation; 6. Aerials; 7. Frequency Modulation Transmitters; 8. Limiters and Discriminators; 9. Frequency Modulation Receivers; 10. Measurements on Frequency Modulation Equipment; 11. Practical Uses of Frequency Modulated Signals. With the exception of Chapter 11 which gives a brief discussion of certain practical applications in other fields, coverage is restricted to accepted techniques employed for the provision of low interference high-fidelity broadcasting services. The first six chapters present theoretical and practical aspects of frequency modulation, radio propagation, and radio antennas which are prerequisite to an understanding of the engineering considerations to which the remainder of the book is devoted. The 254 figures, many of which are new, contribute to the success of the book.

In the application of frequency modulation to low interference high-quality broadcasting services this book, written by engineers for engineers, tells what to do and how to do it. Treatments of engineering procedures and engineering aspects are accompanied by careful discussion, usually by numerical examples, and frequently by actual performance characteristics. The method of operation of each circuit is described concisely and in a manner that promotes easy understanding. Many readers are

likely to appreciate the practice of depicting numerical values of significant circuit elements in a schematic drawing of commercial equipment.

H. S. BLACK
Bell Telephone Laboratories, Inc.
Murray Hill, N. J.

Reference Data for Radio Engineers, 4th ed., ed. by H. P. Westman

Published (1956) by International Telephone & Telegraph Corp., 67 Broad St., N. Y. 4, N. Y. 1121 pages+29 index pages. Illus. 8½×6. $6.00

The widespread acceptance of its earlier editions by engineers in all fields indicates the utility of this compilation of general information. As specialization increases, few engineers can avoid searching for data in their own or in other fields some of which may be but remotely connected to electronic matters. A surprising amount of material has been added to this edition, which is now about six times the size of the first edition.

The material is concisely presented, with enough explanatory data to avoid confusion as to values, terms, and units or the conversions so often encountered with the use of data from diverse sources. Since the earlier editions are so well known we will only call attention to some of the new material introduced. The compilation has been the responsibility of many engineers from among the various divisions of I. T. & T., each contributing in his particular field of specialization, which contribution is then collectively reviewed by a group of engineers having broad experience.

Some of the new or completely revised material now included are: network filter design, transistors and their circuitry, probability and statistics, information theory, magnetic amplifiers, metallic rectifiers, scattering matrixes in waveguides, scatter propagation, television pick-up tubes, nuclear physics, patent practices, and much more. Among the unusual and welcome items is a description of materials and processes for printed circuits, industry standards for many components, design practices for handling shock, vibration and other use hazards, patent coverage of inventions, and even a summary of the U. S. military nomenclature system!

This volume will probably be kept close at hand as a "try first" source of information by many engineers.

R. R. BATCHER
Consultant
Douglaston, New York

Recent Books

Arcs in Inert Atmospheres and Vacuum, ed. by W. E. Kuhn. Papers presented at the Symposium on Arcs in Inert Atmospheres and Vacuum of the Electrothermics and Metallurgy Division of the Electrochemical Society, April 30–May 1, 1956, San Francisco, Calif. John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. $7.50.

Berkeley, E. C. and Wainwright, Lawrence, *Computers: Their Operation and Applications*. Reinhold Publishing Corp., 430 Park Ave., N. Y. 22, N. Y. $8.00.

Equivalent Radio Tubes Vade-Mecum, 13th ed., ed. by J. A. Gijsen. P. H. Brans, Ltd., Antwerp, Belgium.

Eustis, William, *A Primer to the Automatic Office*. Automation Management, Inc., Westboro, Mass. $7.50.

Lanczos, Cornelius, *Applied Analysis*. Prentice-Hall, Inc., 70 Fifth Ave., N. Y. 11, N. Y. $9.00.

Lang, D. G., *Marine Radar*. Pitman Publishing Corp., 2 W. 45 St., N. Y. 36, N. Y. $4.75.

Lessing, Lawrence, *Man of High Fidelity: Edwin Howard Armstrong*. J. B. Lippincott Co., East Washington Square, Philadelphia, Pa. $5.00.

Mueller, G. V., *Introduction to Electrical Engineering*, 3rd ed. McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. $7.50.

Proceedings of the CERN Symposium on High Energy Accelerators and Pion Physics (Geneva, Switzerland, June, 1956). The two volumes are obtainable from CERN Service d'Information, Case postale 25, Geneva 15, Switzerland. 40 Swiss francs per volume.

Proceedings of the RETMA Symposium on Reliable Applications of Electron Tubes. Engineering Publishers, GPO Box 1151, N. Y. 1, N. Y. Paperbound. $5.00.

Thourel, L., *Les Antennes*. Dunod, 92, rue Bonaparte, Paris 6, France. 4.800 F.

Professional Groups†

Aeronautical & Navigational Electronics—Joseph General, 6019 Highgate Dr., Baltimore 15, Md.

Antennas & Propagation—H. G. Booker, School of Physics and Elec. Engrg., Cornell Univ., Ithaca, N. Y.

Audio—D. W. Martin, The Baldwin Piano Company, 1801 Gilbert Ave., Cincinnati 2, Ohio.

Automatic Control—J. C. Lozier, Bell Tel. Labs., Whippany, N. J.

Broadcast & Television Receivers—L. R. Fink, Research Lab., General Electric Company, Schenectady, N. Y.

Broadcast Transmission Systems—O. W. B. Reed, Jr., Jansky & Bailey, 1735 DeSales St., N.W., Washington, D. C.

Circuit Theory—H. J. Carlin, Microwave Res. Inst., Polytechnic Inst. of Brooklyn 55 Johnson St., Brooklyn 1, N. Y.

Communications Systems—F. M. Ryan American Telephone and Telegraph Co., 195 Broadway, New York 7, N. Y.

Component Parts—R. M. Soria, American Phenolic Corp., 1830 S. 54 Ave., Chicago 50, Ill.

Electron Devices—R. R. Law, CBS-Hytron, Danvers, Mass.

Electronic Computers—J. D. Noe, Div. of Engineering Research, Stanford Research Institute, Stanford, Calif.

Engineering Management—Rear Adm. C. F. Horne, Jr., Convair, Pomona, Calif.

Industrial Electronics—C. E. Smith, Consulting Engineer, 4900 Euclid Ave., Cleveland 3, Ohio.

Information Theory—M. J. Di Toro, Polytech. Research & Dev. Corp., 200 Tillary St., Brooklyn, N. Y.

Instrumentation—F. G. Marble, Boonton Radio Corporation, Intervale Road, Boonton, N. J.

Medical Electronics—V. K. Zworykin, RCA Labs., Princeton, N. J.

Microwave Theory and Techniques—H. F. Englemann, Federal Telecommunication Labs., Nutley, N. J.

Military Electronics—C. L. Engleman, 2480 16 St., N.W., Washington 9, D. C.

Nuclear Science—W. E. Shoupp, Westinghouse Elec. Corp., Commercial Atomic Power Activities, P.O. Box 355, Pittsburgh 30, Pa.

Production Techniques—R. R. Batcher, 240-02—42nd Ave., Douglaston, L. I., N. Y.

Reliability and Quality Control—Victor Wouk, Beta Electric Corp., 333 E. 103rd St., New York 29, N. Y.

Telemetry and Remote Control—C. H. Hoeppner, Radiation, Inc., Melbourne, Fla.

Ultrasonics Engineering—J. F. Herrick, Mayo Foundation, Univ. of Minnesota, Rochester, Minn.

Vehicular Communications—Newton Monk, Bell Labs., 463 West St., N. Y., N. Y.

† Names listed are group Chairmen.

Sections*

Akron (4)—C. O. Lambert, 1144 Roslyn Ave., Akron 20, Ohio; M. L. Kult, 1006 Sackett Ave., Cuhahoga Falls, Ohio.

Alamagordo-Holloman (6)—O. W. Fix, Box 915, Holloman AFB, N. M.; T. F. Hall, Box 824, Holloman AFB, N. M.

Albuquerque-Los Alamos (7)—G. A. Fowler, 3333—49 Loop, Sandia Base, Albuquerque, N. M.; S. H. Dike, Sandia Corp., Dept. 5120, Albuquerque, N. M.

Atlanta (3)—M. D. Prince, 3821 Stoland Dr., Chamblee, Ga.; P. C. Toole, 605 Morningside Dr., Marietta, Ga.

Baltimore (3)—M. I. Jacob, 1505 Tredegar Ave., Catonsville 28, Md.; P. A. Hoffman, 514 Piccadilly Rd., Baltimore 4, Md.

Bay of Quinte (8)—R. L. Smith, Northern Electric Co., Ltd., Box 400, Belleville, Ont., Canada; M. J. Waller, R.R. 1, Foxboro, Ont., Canada.

Beaumont-Port Arthur (6)—J. G. Morgan, 508 Garland St., Beaumont, Tex.; B. J. Ballard, Box 2831, Rm. 608, Beaumont, Tex.

Binghamton (1)—Arthur Hamburgen, 926 Glendale Drive, Endicott, N. Y.; Y. M. Hill, 2621 Smith Dr., Endicott, N. Y.

Boston (1)—R. L. McFarlan, 20 Circuit Rd., Chestnut Hill 67, Mass.; T. F. Jones, Jr., 62 Bay St., Squantum, Mass.

Buenos Aires—A. H. Cassiet, Zavalia 2090 1 "B," Buenos Aires, Argentina; O. C. Fernandez, Transradio Internacional, 379 San Martin, Buenos Aires, Argentina.

Buffalo-Niagara (1)—G. F. Buranich, Route 1, Lewiston, N. Y.; Earl Whyman, 375 Mt. Vernon Rd., Snyder 21, N. Y.

Cedar Rapids (5)—J. L. Dalton, 2900 E. Ave., N.E., Cedar Rapids, Iowa; S. M. Morrison, 2034 Fourth Ave., S.E., Cedar Rapids, Iowa.

Central Florida (3)—G. F. Anderson, Radiation, Inc., P.O. Box "Q," Melbourne, Fla.; J. W. Downs, 1020 Highland Ave., Eau Gallie, Fla.

Central Pennsylvania (4)—R. E. Skipper, 276 Ellen Ave., State College, Pa.; S. A. Bowhill, Dept. of Elec. Eng., Penn. State Univ., University Park, Pa.

Chicago (5)—R. M. Soria, 1830 S. 54th Ave., Chicago 50, Ill.; G. H. Brittain, 3150 Summit Ave., Highland Park, Ill.

China Lake (7)—C. F. Freeman, 100-B Halsey St., China Lake, Calif; P. K. S. Kim, 200-A Byrnes St., China Lake, Calif.

Cincinnati (4)—F. L. Weidig, Jr., 3819 Davenant Ave., Cincinnati 13, Ohio; H. E. Hancock, R. R. 4, Branch Hill Box 52, Loveland, Ohio.

Cleveland (4)—J. F. Keithley, 22775 Douglas Rd., Shaker Heights 22, Ohio; C. F. Schunemann, 2021 Sagamore Dr., Euclid 17, Ohio.

Columbus (4)—T. E. Tice, 2214 Jervis Rd., Columbus 21, Ohio; G. R. Jacoby, 78 N. James Rd., Columbus 13, Ohio.

Connecticut Valley (1)—B. R. Kamens, 94 Admiral Dr., New London, Conn.; J. D. Lebel, Benedict Hill Rd., New Canaan, Conn.

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Annual Conference on Electronics in Industry

ILLINOIS INSTITUTE OF TECHNOLOGY, CHICAGO, ILLINOIS
APRIL 9–10, 1957

Tuesday, April 9
Morning

Registration.

Welcoming Address, E. H. Schulz, Director of Elec. Eng., Armour Res. Found.

Introduction, Eugene Mittelmann, consulting engineer.

SESSION I

Chairman: E. H. Jones, Northwestern Univ.

Basic Instrumentation, W. A. Wildhack, National Bureau of Standards.

Communication Problems Between Instruments, Controls and Man, H. B. Ziebolz, Askania Regulator Co.

Economic and Technical Aspects of Industrial Electronics, E. D. Cook, G. E. Co.

Noon

Lunch

Afternoon

SESSION II

Chairman: E. A. Keller, Panellit Corp.

Electronics in a Chemical Company, R. C. McMillen, E. I. duPont de Nemours & Co.

Principles and Techniques for Direct Reading Digital Transducers, W. H. Kliever, consultant.

Process Monitoring by Dielectric Constant, W. H. Howe, The Foxboro Co.

Panel Discussion.

Thursday, April 10
Morning

SESSION III

Chairman: Eugene Mittelmann, consulting engineer.

Application of Magnetic Amplifiers in Industrial Instrumentation and Control, W. A. Geyger, Naval Ordnance Laboratory.

Automatic Card Programmed Control of Reversing Rolling Mills, E. H. Browning, Westinghouse Elec. Corp.

Solid State Devices in Industrial Electronics, Lloyd DeVore, Stewart-Warner.

Noon

Lunch

Afternoon

SESSION IV

Chairman: R. C. Johnson, Barber-Coleman Co.

Some New Aspects of Nuclear Instrumentation in Industrial Electronics, N. C. Anton, Anton Electronics Labs., Inc.

Some Applications of Analog Computer Techniques to Control System Design, Ernest Goggio, Tammen and Dennison, Inc.

Selection of Reliability Levels in Equipment Design, Harold Gabarino, Armour Res. Found.

Panel Discussion.

Symposium on the Role of Solid State Phenomena in Electric Circuits

ENGINEERING SOCIETIES BUILDING, NEW YORK CITY
APRIL 23–25, 1957

Tuesday morning, April 23

Registration.

Opening Remarks, E. Weber, Polytechnic Institute of Brooklyn.

The Solid State, P. P. Ewald, Polytechnic Institute of Brooklyn.

Physical Phenomena of the Solid State, R. C. Fletcher, Bell Telephone Laboratories.

Circuit Aspects of Solid State Phenomena, E. W. Herold, Radio Corporation of America.

Afternoon

BASIC PROCESSES AND TECHNIQUES

The Versitron—A New Solid State Quantum Mechanical Amplifier, M. W. P. Strandberg, Massachusetts Institute of Technology.

The Solid State Maser, J. O. Artman, Harvard University.

Ferroelectrics, W. P. Mason, Bell Telephone Laboratories.

Solid State Devices Using Indium Antimonide, T. S. Moss, Royal Aircraft Establishment, England.

Plastic Semiconductors, H. Mark, Polytechnic Institute of Brooklyn.

Wednesday morning, April 24

SEMICONDUCTOR PROPERTIES AND TECHNIQUES

Compound Semiconductors, G. Fischer and W. B. Pearson, National Research Council, Canada.

Quasi-Electric and Quasi-Magnetic Fields in Non-Uniform Semiconductors, H. Kroemer, Radio Corporation of America.

Transit Time Effects in Depletion Layer Transistors at Microwave Frequencies, W. Gartner, Signal Corps Engineering Laboratories.

The Response Time of Diffused Junction Transistors, E. L. Steele and B. R. Gossick, Motorola, Inc.

Electronic Commutators by Means of Minority Carrier Deflection in Semiconductors, G. C. Sziklai and L. R. Hill, Westinghouse Electric Corporation.

Afternoon

MAGNETIC PROPERTIES AND TECHNIQUES

The Use of Superconductors for Sensitive Electrical Measurements, I. M. Templeton, National Research Council, Canada.

Superconductivity and Its Applications to Electric Circuits, H. O. McMahon, Arthur D. Little, Inc.

Domain Theory of Switching, A. Papoulis, Polytechnic Institute of Brooklyn, and T. C. Chen, Burroughs Corp.

Development of Ferrite Materials for Microwave Applications, D. L. Fresh, Trans-Tech, Inc.

Harmonic Generation in Ferrites, E. Stern, Sperry Gyroscope Company.

Thursday morning, April 25

PHOTO-TECHNIQUES

Survey of Photoconductive Processes in High Resistivity Materials, J. Dropkin, Polytechnic Institute of Brooklyn.

Luminescence Effects Having Circuit Applications, R. E. Halsted, General Electric Company.

Photo Conductive Switching Device, A. Bramley and J. Bramley, Allen B. DuMont Laboratories.

Infra-Red and Microwave Modulators Using Germanium, A. F. Gibson and J. W. Granville, Radar Research Establishment, England.

Optical and Electrical Properties of Cadmium Sulfide and Zinc Sulfide Single Crystals and Applications, I. Broser, Fritz Haber Institute, Max Planck Gesellschaft, Germany.

Persistent Internal Polarization and Applications, H. Kallmann and J. Rennert, New York University.

Afternoon

ROUND TABLE DISCUSSION

Moderator: E. W. Herold.

Question: To what extent will the challenging needs of the circuit designer be met by new and unexploited developments in the solid state art?

Abstracts and References

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England, and Published by Arrangement with that Department and the *Electronic and Radio Engineer*, incorporating *Wireless Engineer*, London, England

NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

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The Index to the Abstracts and References published in the PROC. IRE from February, 1955 through January, 1956, is published by the PROC. IRE, April, 1956, Part II. It is also published by *Electronic and Radio Engineer*, incorporating *Wireless Engineer* and included in the March, 1956 issue of that journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

ACOUSTICS AND AUDIO FREQUENCIES

534.2+[538.566:535.4 316
First Correction to the Geometric-Optics Scattering Cross-Section from Cylinders and Spheres—(*See* 414.)

534.2 317
Propagation of [sound] Waves in a Medium with Random Inhomogeneities of the Refractive Index—V. A. Krasil'nikov and A. M. Obukhov. (*Akust. Zh.*, vol. 2, pp. 107–112; April–June, 1956.) A review including 21 references to Russian work.

534.2 318
Focusing of Sound Waves by Inhomogeneous Media—L. M. Brekhovskikh. (*Akust. Zh.*, vol. 2, pp. 124–132; April–June, 1956.) The cases considered include 1) focusing by reflection of a spherical wave at the boundary of an inhomogeneous medium, and 2) waveguide propagation. The region of the caustic is considered in detail.

534.2 319
Waveguide Propagation of Sound in Inhomogeneous Media—Yu. L. Gazaryan. (*Akust. Zh.*, vol. 2, pp. 133–136; April–June, 1956.) The field is calculated of a point source in a horizontally stratified medium, the sound velocity in which varies with height in a specified manner. A similar velocity distribution law has been discussed previously by Epstein (*Proc. Nat. Acad. Sci., Wash.*, vol. 16, pp. 627–637; October 15, 1930, 1931 Abstracts, p. 31) for em waves.

534.2 320
Correlation Properties of a Wave in a Medium with Random Inhomogeneities—L. A. Chernov. (*Akust. Zh.*, vol. 2, pp. 211–216; April–June, 1956.) The coefficients of the longitudinal space autocorrelation of the amplitude and phase are calculated; it is shown that the longitudinal correlation spreads over a longer distance than does the transverse correlation. The coefficients of the time autocorrelation of amplitude and phase fluctuations are also determined. Some experimental results in hydroacoustics are discussed. For related earlier work, see 3233 of 1955.

534.21 321
Experiments on Acoustic Relaxation Processes using Electrical Models—K. Walther. (*Acustica* vol. 6, pp. 245–251; 1956. In German.)

534.232 322
Excitation of a Quartz Radiator Simultaneously at Several Frequencies—G. D. Mikhailov, N. V. Tikhonova and I. M. Yadrova. (*Akust. Zh.*, vol. 2, p. 231; April–June, 1956.) A preliminary note on the excitation of vibrations in a quartz disk at two frequencies not harmonically related. The two exciting oscillators were connected respectively between the common electrode covering one face of the disk and the semicircular electrodes covering the other face.

534.232–14–8 323
Dielectric Heating of Quartz Oscillating in Several Organic Liquids—S. Parthasarathy and V. Narasimhan. (*Z. Phys.*, vol. 145, pp. 508–510; June 15, 1956. In English.) Measurements were made on crystals driven at 8.7 mc and at 2.84 mc; the results indicate that the dielectric heating is greater in liquids of lower sound-absorption coefficient.

534.232–14–8 324
The Output of a Quartz Transducer Oscillating in its Fundamental and Higher Harmonics—S. Parthasarathy and V. Narasimhan. (*Z. Phys.*, vol. 145, pp. 511–514; June 15, 1956. In English.) Measurements were made on a crystal oscillating in various liquids; the observed output is much smaller than predicted by theory.

534.24 325
Use of Layers Preventing the Production of Transverse Waves in the Reflection of a Longitudinal Wave at the Boundary of a Solid Body—M. A. Isakovich. (*Akust. Zh.*, vol. 2, pp. 150–153; April–June, 1956.)

534.26 326
Scattering and Radiation of Waves by Statistically Inhomogeneous and Statistically Oscillating Surfaces—M. A. Isakovich. (*Akust. Zh.*, vol. 2, pp. 146–149; April–June 1956.) Extension of previous work (2969 of 1953); see also 2541 of 1953 (Eckart).

534.26 327
Scattering of Sound Waves by Sinusoidal and Sawtooth Surfaces—A. N. Leporski. (*Akust. Zh.*, vol. 2, pp. 177–181; April–June, 1956.) An experimental investigation is reported. The results are compared with Lysanov's theory (see 328 below).

534.26 328
An Approximate Solution of the Problem of Scattering of Sound Waves at an Irregular Surface—Yu. P. Lysanov. (*Akust. Zh.*, vol. 2, pp. 182–187; April–June, 1956.) The calculation is based on the solution of an approximate integral equation for the normal component of the velocity potential at the scattering surface.

534.3:534.78 329
Some Results of an Analysis of a Singer's Voice—S. N. Rzhevkin. (*Akust. Zh.*, vol. 2, pp. 205–210; April–June, 1956.) The frequency characteristics of a trained bass voice and an untrained baritone voice are presented graphically and discussed.

534.6–8 330
Differential Method of Measuring the Absorption of Ultrasonic Waves in Liquids—I. G. Mikhailov and G. N. Feofanov. (*Akust. Zh.*, vol. 2, pp. 194–198; April–June, 1956.)

534.61 331
Absolute Method for Sound Intensity Measurement—D. R. Pardue and A. L. Hedrich. (*Rev. Sci. Inst.*, vol. 27, pp. 631–632; August, 1956.) The method described is based on measurement of the temperature variations associated with the sound wave, using a thermometer with a very fast response

534.7 332
The Unity of Speech and Hearing—H. Mol. (*PTT-Bedrijf*, vol. 7, pp. 69–75; July, 1956.) The interdependence of the two functions in communication by language and the shortcomings of purely objective measurements are stressed.

534.845 333
The Absorption of Sound in Air at Audio Frequencies—E. J. Evans and E. N. Bazley. (*Acustica*, vol. 6, pp. 238–245; 1956.) Measurements have been made in a large reverberation chamber with very small surface absorption, at frequencies from 1 kc to 12.5 kc, for values of relative humidity from about 5 per cent to 85 per cent and a temperature of 20°C. The values obtained for the absorption due to the air are in close agreement with values given by relaxation theory. A general expression is

derived for the attenuation of sound in air as a function of frequency, humidity, and temperature.

621.395.61.089.6:534.612 334
The Thermophone, an Aerodynamic Pistonphone—P. Riéty. (*Acustica*, vol. 6, pp. 251–258; 1956. In French.) Rigorous theory presented previously (657 of 1956) is supplemented by a discussion based on the physical processes, *i.e.*, energy transformations, in the thermophone. The operation of the device is compared with that of the pistonphone. A formula derived for the acoustic pressure inside the thermophone is identical with that obtained previously. The device is of interest for calibrating microphones, though not so accurate as the reciprocity method.

ANTENNAS AND TRANSMISSION LINES

621.372 335
The Launching of a Plane Surface Wave—G. J. Rich. (*Proc. IEE*, Part B, vol. 103, pp. 787–788; November, 1956.) Discussion on 1548 of 1955.

621.372.2 336
Theory of Helical Line Surrounded by a Cylindrical Semiconducting Envelope—E. G. Solov'ev and L. V. Belous. (*Radiotekhnika, Moscow*, vol. 11, pp. 31–35; April, 1956.) The propagation of em waves along a helix inside a quartz tube coated with a semiconducting layer is discussed. An equation is derived indicating the dependence of the attenuation on the thickness d of the semiconducting layer, the conductivity σ, retardation and frequency. Curves show the calculated and observed dependence of the attenuation on $\sigma \cdot d$.

621.372.2:621.372.8 337
Surface Electromagnetic Waves on a Comb Structure—L. A. Vainshtein. (*Zh. Tekh. Fiz.*, vol. 26, pp. 385–397; February, 1956.) Theory is developed based on the functional equations used in the rigorous theory of radiation from the open end of a waveguide. An exact characteristic equation of the surface waves is derived, as well as a simplified approximate form; a method is proposed for estimating the accuracy of the latter equation. Curves show the dispersion properties of periodic comb structures.

621.372.2+621.372.8]:621.385.029.6 338
Electron Waves in Retarding Systems—L. A. Vainshtein. (*Zh. Tekh. Fiz.*, vol. 26, pp. 126–140, 141–148; January, 1956.) The linear theory of electron waves in retarding systems is discussed in relation to the excitation of waveguides. The characteristic wave equation is derived and its solutions are studied. The physical meaning of the quantities appearing in the equation is established. The following particular retarding systems are considered: 1) waveguide filled with a dielectric, 2) transmission line of comb type and 3) helical line. The results obtained are compared with those published in the literature.

621.372.21 339
Free Oscillations in Simple Distributed Circuits—A. B. Hillan. (*Wireless Eng.*, vol. 33, pp. 279–290; December, 1956.) Analysis is presented for a representative distributed circuit in the form of a finite length of uniform transmission line, 1) with a pure inductance at one end and an open-circuit at the other, or 2) with a pure capacitance at one end and a short-circuit at the other. Distinction is drawn between the cases where the energy is initially stored in the lumped-circuit element and where it is stored in the line. The method is useful for determining the effect of measuring circuits and cables on line waveforms.

621.372.8 340
A Low-Attenuation Waveguide Free From Phase and Attenuation Distortion—H. G. Unger. (*Arch. Elekt. Übertragung*, vol. 10, pp. 253–260; June, 1956.) For the H_{0l} mode in a circular metal waveguide with a suitably dimensioned coaxial inner tube of low-loss dielectric, the attenuation/frequency curve exhibits a minimum and the group-velocity /frequency curve exhibits an extreme value at the same frequency, at which propagation is hence free from distortion. For wide-band applications, the diameter and wall thickness of the dielectric tube must be small.

621.372.8 341
Influence of a Semiconducting Film on the Attenuation of Radio Waves in Waveguides with Circular Cross-Section—V. V. Malin. (*Radiotekhnika i Elektronika*, vol. 1, pp. 34–37; January, 1956.) The attenuation of H_{0m}, E_{0m} and E_{nm} waves in a cylindrical waveguide whose inner surface is coated with a material having a complex permittivity is calculated. The formulas derived are valid for $\epsilon'' \ll \epsilon'$ and $\epsilon'' \gg \epsilon'$ as well as for $\epsilon'' \approx \epsilon'$. Graphs show that the maximum attenuation for all modes except the H_{0m} occurs at $\epsilon'' \simeq \epsilon'$; it is assumed that the film is thick compared with the surface film of the metal.

621.372.8 342
Scattering by a Semi-infinite Resistive Strip of Dominant-Mode Propagation in an Infinite Rectangular Waveguide—V. M. Papadopoules. (*Proc. Camb. Phil. Soc.*, vol. 52, pp. 553–563; July, 1956.) A calculation is made, using Laplace transforms, of the scattering produced by a strip arranged parallel to the electric field in the mid-plane of the waveguide. Formulas are derived for the amplitude of the scattered waves, and numerical results are given for various values of the surface resistivity of the strip.

621.372.8:621.318.134:538.221 343
Relations between the Structure of Ferrites and Conditions for their Resonance in Waveguides. Unidirectional Guides—Suchet. (See 512.)

621.396.67+[621.372.8:538.63]+621.396.11 +[538.566:535.42/.43 344
Symposium on Electromagnetic Wave Theory—(See 415.)

621.396.674.3:621.396.93 345
The Use of a Horizontal Dipole as a Direction-Finding Antenna—G. Millington. (*Marconi Rev.*, vol. 19, pp. 97–118; 3rd Quarter 1956.) The problem is considered in relation to the type of wave radiated by the transmitter, neglecting site, and instrumental errors. Conditions are analyzed for both small and large angles of elevation at the receiver: examples show that errors may be very large in the latter case. A comparison is made between the vertical-frame and horizontal-dipole antennas for u.s.w. d.f.; the nature and order of bearing errors are similar for the two types.

621.396.677 346
Ground Antennas—J. Grosskopf. (*Nachrichtentech. Z.*, vol. 9, pp. 241–244; June, 1956.) Simple analysis indicates that the performance of ground antennas can be predicted both qualitatively and quantitatively from accepted theory; freedom from noise is no greater than for other types of antenna. Measurements on several different systems support this view.

621.396.677 347
Investigations of Ground Antennas (Long-Wave Directional Receiving Installations)—W. Kronjäger and K. Vogt. (*Nachrichtentech. Z.*, vol. 9, pp. 245–249; June, 1956.) Symmetrical antennas were used in the measurements reported, on account of their relative insensitivity to local noise. The results indicate that these antennas have similar receiving properties to a frame antenna with vertical axis of rotation. At a communication station with sufficient ground space for a crossed ground antenna, such an antenna is on account of its simplicity, preferable to an equivalent crossed-frame system.

621.396.677 348
An Experimental Design Study of some S- and X-Band Helical Antenna Systems—G. C. Jones. (*Proc. IEE*, Part B, vol. 103, pp. 764–771; November, 1956.) The general characteristics of helical antennas are summarized, and measurements of radiation patterns are reported for single and multiple types. Methods such as end loading and tapering are discussed for increasing beam width and bandwidth. Satisfactory techniques have been developed for sealing the helices inside foamed insulating materials to improve their rigidity. Wide-band antennas giving linearly polarized radiation can be produced using rectangular helices.

621.396.677:523.16 349
Radio Astronomy and the Jodrell Bank Telescope—Lovell. (See 421.)

621.396.677.3 350
Note on the Fourier Coefficients for Tchebycheff Patterns—H. E. Salzer. (*Proc. IEE*, Part C, vol. 103, pp. 286–288; September, 1956.) A formula derived for the feeding coefficients for optimum beam patterns for antennas is equivalent to a set of formulas given by Duhamel (2225 of 1953) but is more convenient for computation.

621.396.677.3 351
The Determination of the True Side-Lobe Level of Long Broadside Arrays from Radiation-Pattern Measurements made in the Fresnel Region—R. H. T. Bates and J. Elliott. (*Proc. IEE*, Part C, vol. 103, pp. 307–312· September, 1956.)

621.396.677.3 352
Influence of a Parasitic Antenna in a Rectangular Array—G. Boudouris. (*J. Brit. IRE* vol. 16 pp. 571–584; October, 1956.) "A rectangular antenna array has a parasitic element placed at its center. All the antennas making up the array are symmetrical half-wave dipoles parallel to one another and not displaced in the sense of their axes, and the system radiates in free space. The antennas are assumed to be thin and in the form of wires. Radiation diagrams and the gain of the network are considered from the double standpoint of the influence of the parasitic element and of the geometric configuration of the rectangle. The formulas produced are developed in the form of graphs. Some comments relative to the case of earthed dipoles are given." See also 554 of 1950.

621.396.677.3:621.372.6 353
N-Terminal Networks—Bloch. (See 383.)

621.396.677.31 354
Optimal Linear Arrays of Antennas, Radiating Perpendicular to the Axis—V. L. Pokrovski. (*C.R. Acad. Sci. U.R.S.S.*, vol. 109, pp. 769–770; August 1, 1956. In Russian.) The problem considered previously by Dolph (2487 of 1946) is solved for arbitrary radiator spacing. The calculation is carried out for arrays with symmetry about a mid-point, but the calculated optimum current distribution applies to all linear arrays

621.396.677.71 355
Radiation Patterns of Circumferential Slots on Moderately Large Conducting Cylinders—J. R. Wait and J. Kates. (*Proc. IEE*, Part C, vol. 103, pp. 289–296; September, 1956.) "Computed patterns are presented for thin half-wave circumferential slots on circular con-

ducting cylinders of infinite length. The cases considered are for single and diametrically opposed slots on cylinders whose circumferences vary from 3 to 21 wavelengths."

621.396.677.8 356

Wide-Angle Scanning Performance of Mirror Antennas—J. F. Ramsay and J. A. C. Jackson. (*Marconi Rev.*, vol. 19, pp. 119–140; 3rd Quarter, 1956.) Design details are discussed of a coma-corrected zoned paraboloidal mirror and a spherical mirror antenna, the latter based on the work of Ashmead and Pippard (1342 of 1947). Results of performance tests on both types using offset feed agree closely. A comparison of mirror and lens antennas shows that mirrors are preferable for line scanning, a lens being more advantageous where a large volume of scan is required. Scanning charts show possible "pin-cushion" and "barrel" distortion; a generalized, approximate chart has been developed for indicating the scanning performance of both mirrors and lenses.

621.396.677.83 357

The Insertion Equivalent of Passive Reflectors [in microwave links]—C. Micheletta. (*Alta Frequenza*, vol. 25, pp. 275–304; June/August, 1956.) An expression is derived which relates the field strength received at an antenna via a deviating reflector to that received at the same antenna without the reflector, over a path of the same total length. By applying the formula to reflectors of various shapes the validity of the usual approximations is assessed. Numerical examples are given for paths with one or two reflectors. The minimum distance to which the formula is applicable is found by comparison with the method of Jakes (1243 of 1953).

621.396.677.85 358

A Study of the Field Distribution at an Axial Focus of a Square Microwave Lens—P. A. Matthews and A. L. Cullen. (*Proc. IEE*, Part C, vol. 103, pp. 449–456; September, 1956.) Discussion indicates that the principal component of the electric field vector can be evaluated with sufficient accuracy from the scalar theory. Measurements of the transverse component of the electric field made by a perturbation method using a spinning dipole, give results in good agreement with theory. The 180° phase shift associated with passage of a wave through the focal plane is considered; the related change in wavelength near the focus is verified experimentally.

AUTOMATIC COMPUTERS

681.142 359

Transistor/Magnetic Analogue Multiplier—G. L. Keister. (*Electronics*, vol. 29 pp. 160–163; October, 1956.) A four-quadrant voltage multiplier using magnetic cores and junction-transistor switches is described, giving an output linear within ±3 per cent. Multiplication is performed by averaging a square wave of which the amplitude is proportional to one input voltage and the phase to the other.

681.142:621.318.134 360

Design of the Components of a Fast-Acting Store using Ferrite Ring Cores—H. Gillert. (*Nachrichtentech. Z.*, vol. 9, pp. 250–252; June, 1956.) The requirements for transmission between line selector and lines and between column selector and columns in matrix storage devices are investigated; design data for the selector-core windings are hence derived. Some details are given of the storage unit in the Darmstadt computer DERA.

681.142:621.383 361

Photoelectric Analogue Function Generator—R. A. Sinker. (*Electronics*, vol. 29, pp. 178–181; October, 1956.) Three-dimensional data stored as density variations on photographic film are read by means of a cr beam and photomultiplier. Satisfactory accuracy for function generation is obtained by providing a grey-scale standard deflection feedback loop and a servo feedback loop controlling light intensity.

CIRCUITS AND CIRCUIT ELEMENTS

621.318.424:621.3.011.3 362

On the Inductance of Iron-Cored Coils—P. Hammond. (*Proc. IEE*, Part C, vol. 103, pp. 249–259; September, 1956.) "The magnetic field in the neighborhood of coils threaded through holes in iron cylinders is calculated. The results are relevant to the estimation of the self-inductance of rotating machines and transformers and form the basis for an examination of the soundness of approximate formulas used in the design of such apparatus."

621.318.57 363

Precision Electronic Switching with Feedback Amplifiers—C. M. Edwards. (Proc. IRE, vol. 44, pp. 1613–1620; November, 1956.) Circuits are described in which precise control of voltage or current levels is achieved by using a high-gain feedback amplifier to minimize differences and nonlinearities in the circuit elements. Applications in analogue computers, signal-comparing devices and communication systems are indicated.

621.319.45 364

Tantalum Capacitors use Solid Electrolyte—D. A. McLean. (*Electronics*, vol. 29, pp. 176–177; October, 1956.)

621.372 365

Nyquist's Stability Criterion—E. A. Freeman and J. F. Meredith. (*Wireless Eng.*, vol. 33, pp. 290–294; December, 1956.) A proof based on Laplace-transform calculus is presented; the analysis is applicable to multiloop as well as single-loop feedback systems.

621.372:534.213–8 366

On the Measurement of Attenuation in Ultrasonic Delay Lines—M. Redwood and J. Lamb. (*Proc. IEE*, Part B, vol. 103, pp. 773–780; November, 1956.) "A theoretical and experimental study has been made of the effects of coupling films on the propagation of compressional waves from a transducer to a solid medium. In practice it has been found that "wringing" the transducer to the specimen with oil as a coupling medium produces a film of nonuniform thickness. Although the variations in thickness are of the order of a wavelength of light, these variations are important at ultrasonic frequencies in the region of 50 mc and above. Conditions are described under which such films can lead to the propagation of a predominantly first-order mode in the specimen, resulting in an exponential decay of the amplitudes of successive reflections, with a consequent improved accuracy of attenuation measurement."

621.372.412:549.514.51 367

Frequency-Temperature-Angle Characteristics of AT-Type Resonators made of Natural and Synthetic Quartz—R. Bechmann. (Proc. IRE, vol. 44, pp. 1600–1607; November, 1956.) Differences between the frequency/temperature characteristics and optimum orientation angles of natural and synthetic quartz resonators are discussed on the basis of detailed experimental and analytical studies. Synthetic quartz with deliberately modified properties can be produced by introducing other substances during the growing process. Measurements are reported on AT-type resonators cut from quartz grown in an alkaline solution containing germanium oxide; the third-order temperature coefficient is noticeably reduced.

621.372.412:621.372.54 368

The Use of Ethylene Diamine Tartrate for Piezoelectric Filter Elements—J. Birch, A. G. Frith, A. C. L. Ferguson, R. H. A.. Miles and J. F. Werner. (*Proc. IEE*, Part C, vol. 103, pp. 420–427; September, 1956.) "Crystal resonators suitable for use in telephone system channel filters have been made from ethylene diamine tartrate (edt). Methods used in the fabrication and mounting of these units are described. The circuits used in the determination of the electrical parameters are given, and the results of a large number of measurements are outlined. Freedom from unwanted resonances over the desired frequency bands combined with the required characteristics has been achieved by suitably dimensioning the plates, and by applying electrodes to a part of the crystal surface only. Increased activity for crystals mounted in air can be obtained by the use of suitably placed reflectors."

621.372.45 369

A Negative Resistance for Direct and Alternating Current—L. Waldmann and R. Bieri. (*Z. Naturf.*, vol. 10a, pp. 814–820; November, 1955.) The negative resistance is constituted by a symmetrical two-terminal tube circuit comprising in its simplest form a twin triode with separate anode resistances. By connecting further twin triodes in parallel and providing cathode resistances, a resistance of about $-3\ k\Omega$ is obtained, constant to within 1.5 per cent at voltages up to ±12 v. The stability limits of the arrangement are discussed. Applications in the field of measurements and analogue technique are indicated.

621.372.5 370

A Method of Analysing the Performance of Tandem-Connected Four-Terminal Networks—P. W. Seymour. (*Proc. IRE, Aust.*, vol. 17, pp. 249–255; July, 1956, *J. Brit. Instn Radio Engrs.*, vol. 16, pp. 555–562; October, 1956.) A graphical technique is presented.

621.372.5 371

Some Properties of the Transfer Function of Unbalanced RC Networks—I. Cederbaum. (*Proc. IEE*, Part C, vol. 103, pp. 400–406; September, 1956.)

621.372.5 372

A Transformation Diagram for Lossy Quadripoles—F. Gemmel. (*Arch. Elekt. Übertragung*, vol. 10, pp. 265–267; June, 1956.) A graphical method is described which, using measured input and termination data, represents separately the transformation of the lossy and loss-free components. The input impedance corresponding to any required terminating impedance can thus be determined.

621.372.5:621.374.5:621–52 373

The Continuous Delay-Line Synthesizer as a System Analogue—J. H. Westcott. (*Proc. IEE*, Part C, vol. 103, pp. 357–366; September, 1956.) The use of a tapped continuous delay line for simulating transfer functions of linear systems is described. The accuracy of the device is estimated with particular reference to servo systems.

621.372.5:621.374.5:621–52 374

Properties of a Feedback-System Analogue based on a Discontinuous-Delay-Line Synthesizer—R. M. F. Houtappel. (*Proc. IEE*, Part C, vol. 103, pp. 367–377; September, 1956.) A simple method is presented for determining the number of sections required for a discontinuous delay line to simulate with a given degree of accuracy the transfer function of a network considered as part of a feedback system.

621.372.5:621.375.2 375

Determination of Optimum Linear-Network Parameters based on Time Characteristics—R. Kulikowski. (*Archiwum Elektrotech.*, vol. 4, pp. 323–346. English summary, pp. 345–346; 1955.) The method of analysis used is based on minimization of the deviation between the input and output functions considered in a

particular function space. Several amplifier circuits are discussed in detail, with emphasis on pulse response.

621.372.5.029.3.018.783 376
Compensation Method of Reducing Nonlinear Distortion—A. A. Gorbachev. (*Radiotekhnika, Moscow*, vol. 11, pp. 67–74; April, 1956.) The principles of a method of compensating distortion by means of distortion voltages or currents fed in phase opposition are considered theoretically. A block diagram of the arrangement is given. Results of an experimental verification in an af power amplifier are tabulated and indicate, in this particular case, a decrease of the coefficient of nonlinearity at the load from 13 per cent to 1.4 per cent at 400 cps, with smaller improvements at higher and lower frequencies.

621.372.54 377
Filter Design by Synthesis—G. De Lotto and M. Trinchieri. (*Alta Frequenza*, vol. 25, pp. 233–274; June/August, 1956.) The application of Darlington's method (*J. Math. Phys.*, vol. 18, pp. 257–353; September, 1939) is detailed. By modifying the attenuation function used in the calculations, compensation for losses in the circuit, and hence a closer approach to the ideal response curve, can be achieved. A numerical example and useful tables are included.

621.372.54 378
Comparison between the Image-Parameter Method and the Modern Insertion-Loss Method of Filter Design—V. Fetzer. (*Arch. Elekt. Übertragung*, vol. 10, pp. 225–240; June, 1956.) The two design methods are outlined; discussion shows that the insertion-loss method is superior, as it permits closer conformity to the required tolerances and a greater freedom in the selection of parameters. The larger amount of calculation necessary can, in special cases, be reduced by reference to a filter catalogue [351 of 1956 (Glowatzki)]. Further applications of the modern method are mentioned. 76 references.

621.372.54:621.315.212 379
V.H.F. Band-II Harmonic Filter—B. M. Sosin. (*Marconi Rev.*, vol. 19, pp. 89–96; 3rd Quarter, 1956.) The design and characteristics of a filter for use in transmitters are described. The filter is of the varying-impedance type [see *e.g.*, 2338 of 1954 (Yin and Foley)] and forms part of a $3\frac{1}{4}$-in-diameter 51.5-Ω coaxial feeder run.

621.372.57.029.6 380
The Equivalent Noise Quadripole Treated as a Wave Quadripole—H. Bauer and H. Rothe. (*Arch. Elekt. Übertragung*, vol. 10, pp. 241–252; June, 1956.) Sources of noise voltage and current are interpreted as waves, to make the equivalent network [2665 of 1956 (Rothe and Dahlke)] applicable to uhf conditions. The relation between matrices based on wave parameters and impedance concepts is derived.

621.372.6 381
New Hybrid Devices for Combining and Distributing Electric Power at High Frequencies—A. A. L'vovich. (*Radiotekhnika, Moscow*, vol. 11, pp. 36–43; April, 1956.)

621.372.6 382
Analysis of Linear *n*-Port Networks—I. Cederbaum. (*Proc. IEE*, Part C, vol. 103, pp. 267–271; September, 1956.) Analysis is presented for the general case of the nonreciprocal *n*-port linear network; using a symbolic notation, a unique expression for all network functions is derived. Examples of the application of the method are given.

621.372.6:621.396.677.3 383
***N*-Terminal Networks**—A. Bloch. (*Wireless Eng.*, vol. 33, pp. 295–300; December, 1956.) Generalized two-terminal-network theorems are used to analyze the directive properties of antenna arrays.

621.373:621.316.729 384
Synchronization of Oscillators by Sloping [-edge] Radio [-frequency] Pulses—E. S. Voronin and R. V. Khokhlov. (*Radiotekhnika i Elektronika*, vol. 1, pp. 79–87; January, 1956.) A theoretical analysis is presented.

621.373.2.029.6 385
Researches into Spark Generation of Microwaves—M. H. N. Potok. (*Proc. IEE*, Part B, vol. 103, pp. 781–787; November, 1956.) The wide frequency band generated by spark generators permits desired ranges to be selected by means of filters. Waveguide filters of post and iris type are suitable for this purpose. Measurements of wavelength and bandwidth are reported; a Boltzmann interferometer was used, with a cro and recording camera.

621.373.4:621.396.61 386
An Analysis of Pulse-Synchronized Oscillators—G. Salmet. (PROC. IRE, vol. 44, pp. 1582–1594; November, 1956.) Problems in the design of high-precision variable-frequency oscillators, as required for communication transmitters, are discussed. The principles of operation of the impulse-governed oscillator [see *e.g.*, 767 of 1951 (Hugenholtz)] are explained. Use of a modified form of the circuit, termed a "phase follower," eliminates the tendency to instability as well as other undesirable characteristics of the IGO.

621.373.421 387
Theory of the Triode Valve Oscillator with Feedback—V. A. Zore. (*Zh. Tekh. Fiz.*, vol. 26, pp. 181–192; January, 1956.) Continuation of a previous paper (2480 of 1949). A general design method is given taking into account the effect of grid current and of electron transit time. The condition of self-excitation and the dependence of the frequency generated on the anode voltage are investigated. A formula is derived for calculating the limiting wavelengths.

621.373.421:621.314.7 388
A Transistor RC Oscillator—G. Francini. (*Alta Frequenza*, vol. 25, pp. 198–210; June/August, 1956.) The substitution of a transistor for a triode is investigated in the RC oscillator with twin-T feedback network described *e.g.* in 3198 of 1955 (Tucker). A single transistor without matching transformer is sufficient because of the low attenuation and high selectivity of the network even at very low frequencies where its impedance rises to about 1MΩ.

621.373.421.14:621.372.413 389
Frequency Control in the 300–1200-Mc/s Region—D. W. Fraser and E. G. Holmes. (PROC. IRE, vol. 44, pp. 1531–1541; November, 1956.) Oscillators controlled by coaxial-cavity resonators are discussed. Frequency stability can be increased ten- to twenty-fold by connecting a small capacitor in series with the resonator. Using a Type-6AF4 tube with an anode voltage of 50–60V, the variation of frequency with voltage is 0.3 cps per mc per volt in the 600-mc region: this compares favorably with overtone-crystal oscillators in their upper frequency range. For frequencies between 700 mc and 1 kmc a control system comprising two cavities arranged end to end is found satisfactory with a pencil triode Type-5876; the series capacitor is constituted by an iris between the two cavities. A resonator tunable over a range of ±15 mc around 600 mc is described. Variations with temperature are minimized by the design.

621.373.423:621.316.729 390
Mutual Synchronization of Reflex Klystrons—R. V. Khokhlov. (*Radiotekhnika i Elektronika*, vol. 1, pp. 88–97; January, 1956.) The possibility of a continuous transition from control by one klystron to control by the other is shown by an analysis of the solutions of van der Pol's equations describing the synchronization process.

621.375.2 391
Negative-Impedance Amplifiers—W. Nowicki. (*Archiwum Elektrotech.*, vol. 4, pp. 279–322. French summary, pp. 318–322, 1955.) An analysis is made of the performance of amplifiers in which negative impedance is introduced by positive feedback. Frequency distion is greater than for other types of line amplifier; stability also is inferior. Such amplifiers are nevertheless useful in certain circumstances since they are very economical of copper.

621.375.221 392
Wide-Band Multistage Amplifiers with Gaussian Characteristics—W. Golde. (*Archiwum Elektrotech*, vol. 4, pp. 215–246. English summary, pp. 245–246; 1955.) Analysis is based on use of the Taylor approximation to the Gaussian function. Typical low-pass and bandpass circuits are examined. The response of such amplifiers to step signals is nearly monotonic overshoots being ≥ 1 per cent for the number of stages commonly used. A comparison of asynchronous and synchronous types indicates that the former give better pulse response.

621.375.227 393
A Differential Amplifier of high Input Impedance for Suppression of [unbalanced] Earth Voltages—A. P. Bolle and D. Capel. (*PTT-Bedrijf*, vol. 7, pp. 58–63; July, 1956.) The circuit described covers a frequency band from 10 kc to 1 or 2 mc. Consideration is given to the rejection factor [see also 362 of 1956 (Klein)], which varies with frequency and according to the adjustment of the balancing network.

621.375.23 394
Nonlinear-Amplifier Design for Pulse-Height Analysers—G. W. Hutchinson. (*Rev. Sci. Instr.*, vol. 27, pp. 592–596; August, 1956.) "The ratio of maximum to minimum pulse sizes which can be simultaneously recorded by a kick sorter is limited by the curvature of the characteristic of its biased amplifier over a finite region of input potentials. The extent of this region can be reduced from a few volts to about 10 mV by including the nonlinear elements of the amplifier in its negative feedback loop. An amplifier is described which embodies this principle and also provides a discriminator and gate circuit."

621.375.4:621.314.7 395
Gain Chart for Transistor Amplifiers—G. H. Myers. (*Electronics*, vol. 29, pp. 224, 226; October, 1956.)

621.375.4:621.314.7 396
Common-Emitter Transistor Video Amplifiers—G. Bruun. (PROC. IRE, vol. 44, pp. 1561–1572; November, 1956.) Design theory applicable to alloy-junction transistors makes use of the hybrid-Π equivalent network. The bilateral nature of the transistor is taken into account by adding a "Miller" capacitance term to the diffusion capacitance. Gain-bandwidth products and optimum load resistances are determined for cascaded stages. The production of maximally flat frequency response in a single stage by means of a capacitor shunting the feedback resistor or by means of inductances in the interstage couplings is discussed.

621.375.5 397
Resonant Dielectric Amplifier—M. Vadnjal. (*Alta Frequenza*, vol. 25, pp. 211–232; June/August, 1956.) The solution of a second-order

differential equation yields an expression for the amplification in terms of all the circuit parameters. Hence the optimum voltage and power amplification, the distortion, and the frequency response are easily determined [see also 2903 of 1954 (Penney *et al.*)]. Experimental results confirm the validity of this analysis.

GENERAL PHYSICS

537.312.62 398

Magnetic Energy and Electron Inertia in a Superconducting Sphere—E. G. Cullwick. (*Proc. IEE*, Part C, vol. 103, pp. 441–446: September, 1956.)

537.5 399

Polarization of the Continuous Spectrum in a Gas Discharge—B. V. Paranjape. (*Proc. Phys. Soc.*, vol. 69, pp. 765–768; July 1, 1956.) Arguments based on the velocity distribution of the electrons are advanced to show that the continuous part of the spectrum of a gas discharge may be expected to be polarized.

537.5 400

Electronic Motion in Gases and the Method of Free Paths—L. G. H. Huxley. (*Proc. Phys. Soc.*, vol. 69, pp. 769–771; July 1, 1956.) Discussion on statements made in a paper by Jancel and Kahan (*The Physics of the Ionosphere*, conference report, 1955, p. 365).

537.533 401

Electron Emission from Zinc Crystals subjected to Plastic Deformation—J. Lohff. (*Z. Phys.*, vol. 145, pp. 504–507; June 15, 1956.)

537.533:537.534.8:537.525.8 402

Auger Ejection of Electrons from Barium Oxide by Inert Gas Ions and the Cathode Fall in Normal Glow Discharges—Y. Takeishi. (*J. Phys. Soc. Japan*, vol. 11, pp. 676–689; June, 1956.) Calculated total yields and energy distribution for He, Ne, Ar, Kr, and Xe positive ions are high compared with those observed by Hagstrum (681 of 1955) for emission from tungsten; the values for Ar^+ agree with those observed by Varney (2357 of 1954). Cathodic phenomena observed were in agreement with theory

537.533:537.58 403

Thermionic Emission Constants of Iridium—D. L. Goldwater and W. E. Danforth. (*Phys. Rev.*, vol. 103, pp. 871–872; August 15, 1956.) Measurements on ribbon specimens subjected to prolonged cleaning are reported; the values found for the constants A and ϕ are respectively 170 A/cm² per (deg C)² and 5.40 v. The spectral emissivity is 0.33 at $\lambda = 0.65\mu$.

537.533:621.385.032.21 404

Field Emission and Field-Emission Cathodes—Zernov and Elinson. (See 637.)

537.534 405

Mass-Spectrometer Investigations of the Field Emission of Positive Ions—M. C. Inghram and R. Gomer. (*Z. Naturf.*, vol. 10a, pp. 863–872; November, 1955.) Preliminary experiments indicate that the combination of the field-emission source and the mass spectrometer is likely to be useful for investigating various phenomena such as adsorption processes etc.

537.56 406

Theory of Plasma Resonance—P. A. Wolff. (*Phys. Rev.*, vol. 103, pp. 845–850; August 15, 1956.) "Starting from the Boltzmann transport equation, a formula is derived for the rate of change of electron density in a gas plasma. With its aid a study is made of the oscillations of electron density (about the steady state value) in a discharge confined between parallel plates. The oscillations are described in terms of a set of normal modes characteristic of the plasma under study. An expression is obtained for the impedance of the discharge as a function of frequency: for the one case calculated in detail, this formula gives a resonance in power absorption at a frequency of 0.7 of the plasma resonance frequency corresponding to the central electron density."

537.56 407

Helmholtz Instability of a Plasma—T. G. Northrop. (*Phys. Rev.*, vol. 103, pp. 1150–1154; September 1, 1956.)

537.56 408

The Extraction of Ions from Plasmas and Plasma-Like System—W. Fischer and W. Walcher. (*Z. Naturf.*, vol. 10a, pp. 857–863; November, 1955.) Report of an experimental and theoretical investigation of the extraction mechanism; conclusions are drawn regarding the limits of applicability of probe theory and of the term "plasma."

537.56 409

Recording Decay of Electron Density in Ionized Gases—G. E. Deakins and C. M. Crain. (*Rev. Sci. Inst.*, vol. 27, pp. 606–608; August, 1956.) The electron density was measured and recorded photographically at times up to 500 μs after removal of a 24.5-mc ionizing voltage, using a cavity-resonator refractometer operating at about 9.4 kmc. Observations indicate that for commercial neon 90 per cent of the decay occurred within the first 250 μs.

537.56:538.56:538.6 410

The Boltzmann Equation and the One-Fluid Hydromagnetic Equations in the Absence of Particle Collisions—F. G. Chew, M. L. Goldberger, and F. E. Low. (*Proc. Roy. Soc. A*, vol. 236, pp. 112–118; July 10, 1956.) "Starting from the Boltzmann equation for a completely ionized dilute gas with no interparticle collision term but a strong Lorentz force, an attempt is made to obtain one-fluid hydromagnetic equations by expanding in the ion mass-to-charge ratio. It is shown that the electron degrees of freedom can be replaced by a macroscopic current, but true hydrodynamics still does not result unless some special circumstance suppresses the transport of pressure along magnetic lines of force. If the longitudinal transport of pressure is ignored, a set of self-contained one-fluid hydromagnetic equations can be found even though the pressure is not a scalar."

537.562 411

The Dependence of the Electronic Recombination Coefficient on Temperature and Pressure—I. L. Aptekar' and B. L. Timan. (*Zh. Tekh. Fiz.*, vol. 26, pp. 343–347; February, 1956.) Electronic recombination in gases is examined on the basis of statistical relations. The variation of the recombination coefficient thus determined coincides with that determined experimentally for ionic recombination in air.

537.562 412

The Behaviour of Ion Columns in Pure Gases—A. Müller. (*Z. Phys.*, vol. 145, pp. 469–485; June 15, 1956.) Measurements of recombination and diffusion in oxygen and in inert gases are reported.

538.3 413

Some Problems relating to the Application of Hertzian Vectors—K. Bochenek. (*Archiwum Elektrotech.*, vol. 4, pp. 247–268; English summary, pp. 266–268; 1955.) Two theorems on em fields are presented: in the first, the field is described by only one vector, electric or magnetic; in the second it is described by two vectors.

538.566:535.4]+534.2 414

First Correction to the Geometric-Optics Scattering Cross-Section from Cylinders and Spheres—S. I. Rubinow and T. T. Wu. (*J. Appl. Phys.*, vol. 27, pp. 1032–1039; September, 1956.) "The total scattering cross section in the short-wavelength limit is considered in this paper. The problems treated include diffraction of a plane electromagnetic wave by aconducting cylinder (two possible polarizations) or a conducting sphere, acoustic scattering by a rigid sphere, and quantum-mechanical scattering by an impenetrable sphere."

538.566:535.42/.43]+621.396.11+621.396.67 +[621.372.8:538.63 415

Symposium on Electromagnetic Wave Theory—IRE TRANS, vol. AP-4, pp. 190–586; July, 1956.) Report of a conference held at the University of Michigan in June 1955, giving the text of 45 papers and abstracts of 54 others, together with some discussion; an author index is included. The main material is grouped under the headings 1) boundary-tube problems of diffraction and scattering theory, 2) forward and multiple scattering, 3) antenna theory and microwave optics, and 4) propagation in doubly-refracting media.

538.569.4:535.33 416

Recording Magnetic-Resonance Spectrometer—M. W. P. Strandberg, M. Tinkham, I. H. Solt, Jr, and C. F. Davis, Jr. (*Rev. Sci. Instr.*, vol. 27, pp. 596–605; August, 1956.) "Apparatus especially designed for studying electron paramagnetic resonance is described and discussed. A magnet of novel yokeless design is presented. Field stabilization and modulation procedure is considered. The microwave sample cavity is analyzed to determine conditions for optimum operation. The klystron stabilization problem is examined. Appropriate lumped circuits for low-frequency operation are described. The signal amplification and presentation system is treated in detail."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 417

Flux Measurements of Discrete Radio Sources at Frequencies below 30 Mc/s—H. W. Wells. (*J. geophys. Res.*, vol. 61, pp. 541–545; September, 1956.) Measurements on Taurus A, Virgo A, Cygnus A and Cassiopeia A are reported; the amplitude ratios between pairs of these sources have different values at 26.75 and 18.5 mc.

523.16 418

The Measurement of the Distance of Radio Sources by Interstellar Neutral Hydrogen Absorption—D. R. W. Williams and R. D. Davies. (*Phil. Mag.*, vol. 1, pp. 622–636; July, 1956.) Three different methods are discussed for determining the distances from the absorption spectra. The technique has been applied to the intense sources in Cassiopeia, Cygnus, Taurus, and Sagittarius; some results are presented.

523.16 419

The Low-Frequency Spectrum of the Cygnus (19 N4A) and Cassiopeia (23 N5A) Radio Sources—R. J. Lamden and A. C. B. Lovell. (*Phil. Mag.*, vol. 1 pp. 725–737; August, 1956.) Intensity measurements have been made at frequencies of 16.5, 19.0, 22.6 and 30.0 mc, using the 218-ft-aperture transit radio telescope at Jodrell Bank. The intensity of both sources falls abruptly at frequencies below 22 mc; this is probably due to absorption in an interstellar HII region of average density and extent.

523.16:551.510.535 420

Low-Angle Fluctuations of the Radio Star Cassiopeia as Observed at Ithaca, N.Y., and their Relation to the Incidence of Sporadic E—B. Dueño. (*J. Geophys. Res.*, vol. 61, pp. 535–540; September, 1956.) Observations over the period September 1954–August 1955 are reported. Correlation between the radio-star

fluctuations and the occurrence of E_s was good during midwinter and poor afterwards. The E_s layer would be expected to exert its greatest influence over the incoming radiation from Cassiopeia during midwinter, since the radiation then pierces through the ionosphere at a height of 400 km, about 1500 km north of Ithaca; at this point the normal sun-controlled forms of ionization would be at a minimum.

523.16:621.396.677 421

Radio Astronomy and the Jodrell Bank Telescope—A. C. B. Lovell. (*Proc. IEE*, Part B, vol. 103 pp. 711–721; November, 1956.) Text of the 47th Kelvin lecture. The 250-ft-aperture steerable radio telescope is to be used for studying both galactic and extragalactic sources of rf radiation over a wide frequency range. It will also be used as a combined transmitter and receiver for studies of the moon, and possibly of the planets. Very faint meteors and various solar/terrestrial relationships of particular importance to the International Geophysical Year will also be investigated. 57 references.

523.16:621.396.822:523.75 422

Absorption of Cosmic Radio Noise at 22.2 Mc/s Following Solar Flare of February 23rd 1956—S. E. Forbush and B. F. Burke. (*J. Geophys. Res.*, vol. 61, pp. 573–575; September, 1956.) Absorption effects noted in records obtained at an observatory near Washington are briefly discussed.

523.5:621.396.96 423

Diurnal Variations in Forward-Scattered Meteor Signals—C. O. Hines. (*J. Atmos. Terr. Phys.* vol. 9, pp. 229–232; October, 1956.)

523.75:551.510.535:621.396.11.029.45 424

V.L.F. Phase Shifts associated with the Disturbance of February 23rd 1956—Pierce. (See 557.)

550.3 425

A Method for Drawing the Great-Circle Path between Any Two Points on Earth—J. H. Meek. (*J. Geophys. Res.*, vol. 61, pp. 445–448; September, 1956.)

550.38:551.594.6 426

Arc Lengths along the Lines of Force of a Magnetic Dipole—S. Chapman & M. Sugiura. *J. Geophys. Res.*, vol. 61, pp. 485–488; September, 1956.) Formulas and tables for the arc length along the lines of force of a magnetic dipole are given with reference to the earth treated as a sphere. These tables may prove useful in connection with the study of radio whistlers and of the motion of charged particles along the lines of geomagnetic force.

550.380.8+550.37 427

Constructional Details of the Inductive Magnetic-Pulsation and Earth-Current Measuring Equipment at the Geomagnetic Observatory at Fürstenfeldbruck [W. Germany]—K. Burkhart. (*Geofis. Pura Appl.*, vol. 33, pp. 78–85; January–April, 1956. In German.)

550.380.8:621.317.444 428

High-Altitude Measurements of the Earth's Magnetic Field with a Proton Precession Magnetometer—Cahill and Van Allen. (See 526.)

550.385 429

Mean Results of Geomagnetic Observations in Tromsø, Norway for the Years 1930–50—J. Frøshaug. (*J. Geophys. Res.*, vol. 61, pp. 435–444; September, 1956.) Summarized tables of results are presented; graphs show short-term and long-term variations.

550.385:550.37 430

The Origin of Earth Currents and their Probable Influence on the Earth's Magnetic Field—K. Burkhart. (*Geofis. Pura Appl.*, vol. 33, pp. 49–77; January–April, 1956. In German.) For short distances between measuring points a definite relation between earth currents and magnetic variations is generally confirmed. To explain discrepancies over longer distances, not only the subsoil resistance within the area of measurement but the total earth current circuit must be considered. Anomalies in Japan and North Germany are analyzed in relation to the gradient of conductivity normal to the induced emf. Observations agree satisfactorily with theory based on inductively coupled circuits

551.5 431

Pulsed Searchlighting the Atmosphere—S. S. Friedland, J. Katzenstein, and M. R. Zatzick. (*J. Geophys. Res.*, vol. 61, pp. 415–434; September, 1956.) An optical reflection technique which has been used to measure the density profile of the upper atmosphere up to a height of 40 km uses a 50-Mlm light pulse of duration 20μs from a lamp at the focus of a 60-in. mirror, with a photomultiplier at the focus of a similar mirror. The results are in agreement with those obtained by previous investigators and by theoretical methods.

551.5 432

Circulation in the Upper Atmosphere—P. S. Pant. (*J. Geophys. Res.*, vol. 61, pp. 459–474; September, 1956.) A study covering the height range 20–100 km over the northern hemisphere. Summer and winter temperatures computed from the wind field, using rocket mean-pressure data and assuming that the wind field is geostrophic, agree with direct observations. Possible causes of observed seasonal temperature changes are discussed. 48 references.

551.51 433

Gravitational and Thermal Oscillations in the Earth's Upper Atmosphere—M. L. White. (*J. Geophys. Res.*, vol. 61, pp. 489–499; September, 1956.) Analysis given previously [1404 of 1956 (Sen and White)], for the case where heat is introduced only at the base of the atmosphere, is extended to apply to cases where heat is introduced at any region. Expressions obtained for the velocity components and pressure variation at any height are identical with the corresponding equations for the purely gravitational case, except for a new interpretation of the wave function. Expressions are also obtained for the vertical and horizontal displacements and for the amplification over equilibrium tide at any level. Results of the analysis are compared with those obtained by other workers.

551.510.535 434

The Ionization of the E Layer—H. Pichler. (*Geofis. Pura Appl.*, vol. 33, pp. 146–152; January–April, 1956. In German.) The effect of geographical location, season, and solar activity on the relation between the critical frequency f_1E and the position of the sun is discussed. Comparison with observations shows that formulas previously derived *e.g.*, by Harnischmacher (1682 of 1950) are inadequate, probably owing to oversimplification, and that more extensive investigations are needed to clarify the correlation.

551.510.535 435

The World-Wide Height Distribution of the F_2 Layer—R. Eyfrig, E. Harnischmacher, and K. Rawer. (*Geofis. Pura Appl.*, vol. 33, pp. 153–162; January–April, 1956. In German.) An analysis is made of (M3000)F_2 maps covering America from high north magnetic latitudes to the magnetic equator, for years of sunspot minimum and maximum respectively. Generally a daily minimum occurs on the magnetic equator and a maximum at a geographical latitude of 40°N, the latter being less pronounced in summer than in winter. A sunrise maximum occurs irrespective of latitude. Increased solar activity is correlated with decreased M values and accentuation of the equatorial minimum.

551.510.535 436

Physical Properties of the Atmosphere from 90 to 300 km—H. K. Kallmann, W. B. White, and H. E. Newell, Jr. (*J. Geophys. Res.* vol. 61, pp. 513–524; September, 1956.) A model atmosphere based on recent experimental and theoretical studies has the following features: molecular oxygen begins to dissociate at a height of about 90 km; at about 130 km about 30 per cent of O_2 is still in the undissociated state; molecular nitrogen begins to dissociate at about 220 km; the concentrations of O_2 and N_2 decrease exponentially with increasing height; the temperature ceases to vary with height at about 360 km. This model gives lower temperatures and densities throughout the ionosphere than have been deduced previously.

551.510.535 437

Daytime Measurement of Positive and Negative Ion Composition to 131 km by Rocket-Borne Spectrometer—C. Y. Johnson and J. P. Heppner. (*J. Geophys. Res.*, vol. 61, p. 575; September, 1956.) Negative ions of mass numbers 46, 32, 29, 22, and 16 were detected, but no positive ions. For night-time measurements, see 1409 of 1956.

551.510.535 438

Neutral Gas Composition of the Upper Atmosphere by a Rocket-Borne Mass Spectrometer—E. B. Meadows and J. W. Townsend, Jr. (*J. Geophys. Res.*, vol. 61, pp. 576–577; September, 1956.) Measurements at heights up to 141.6 km are reported. In addition to the usual constituents of air, components with mass numbers 46 and 23 were detected in the neighborhood of 85 km. See also 437 above.

551.510.535 439

Resonance Scattering by Atmospheric Sodium: Part 2—Nightglow Theory—J. W. Chamberlain and B. J. Negaard. (*J. Atmos. Terr. Phys.*, vol. 9, pp. 169–178; October, 1956.) Continuation of previous discussion [3728 of 1956 (Chamberlain)]. Three models of the nightglow layer are considered in which the primary excitation is concentrated at the bottom of the layer, evenly distributed through the layer, or concentrated at the top of the layer.

551.510.535 440

Resonance Scattering by Atmospheric Sodium: Part 3—Supplementary Considerations—D. M. Hunten. (*J. Atmos. Terr. Phys.*, vol. 9, pp 179–183; October, 1956.) For the excitation mechanism assumed, the best model of the sodium layer is that in which the excitation is concentrated at the bottom. Part 2: 439 above.

551.510.535:523.75 441

Ionospheric Changes associated with the Solar Event of 23 February 1956—C. M. Minnis, G. H. Bazzard, and H. C. Bevan. (*J. Atmos. Terr. Phys.* vol. 9, pp. 233–234; October, 1956.) A discussion based on observations at Singapore, Inverness, and Slough. A magnetic crochet and intense ionospheric absorption were observed characteristic of an important solar flare. Effects associated with the incidence of high-speed and low-speed particles with the incidence of high-speed and low-speed particles and wave radiation are distinguished.

551.510.535:523.78 442

The Response of the Ionosphere to the Solar Eclipse of 30 June 1954 in Great Britain—C. M. Minnis. (*J. Atmos. Terr. Phys.*, vol. 9, pp. 201–209; October, 1956.) "Vertical-incidence measurements of virtual height and critical frequency were made at two points

at which the maximum obscuration of the disk area was 93 per cent and 74 per cent respectively. The change with time in the intensity of the ionizing radiation during the eclipse was computed from the observed variation in f_0F_1; from this change a model has been constructed giving the brightness distribution of the ionizing radiation over the sun's disk. 92 per cent of the radiation was emitted from a uniformly bright disk on which were superposed, near the E and W limbs, small areas having about twice the brightness of the disk and, near the poles, similar areas having about half this brightness. Accurate measurements of the shape and height of the F_2 layer are difficult owing to the proximity of f_0F_1 and f_0F_2, but an approximate analysis shows that no major changes in the height or thickness of the F_2 layer accompanied the considerable fall in f_0F_2 during the eclipse. It has not been possible to make any reliable estimates of α_E' or α_{F1}'."

551.510.535:621.396.11 443
The Calculation of the True Heights of Reflection of Radio Waves in the Ionosphere—W. J. G. Beynon and J. O. Thomas. (*J. Atmos. Terr. Phys.*, vol. 9, pp. 184–200; October, 1956.) The calculation of the true height from the variation of the virtual height of reflection with frequency is discussed for parabolic distributions of electron density. Existing theory is extended to include the case of reflections from contiguous parabolic sections or truncated parabolas, and an expression is derived for the variation of virtual height with frequency in terms of the layer parameters. Methods are indicated for calculating the true critical frequency of a truncated layer in terms of the observed cusp frequency and for deriving the layer parameters.

551.594.21 444
A Theory of Thundercloud Electricity—C. T. R. Wilson. (*Proc. Roy. Soc. A*, vol. 236, pp. 297–317; August 2, 1956.) Theory is developed in which the thundercloud is regarded as an influence machine, the ionization currents associated with it being the agents by which its emf is generated and maintained.

551.594.6:621.396.822 445
An Investigation of Atmospheric Radio Noise at Very Low Frequencies—F. Horner and J. Harwood. (*Proc. IEE*, Part B, vol. 103, pp. 743–751; November, 1956.) Investigating technique is described and typical results obtained in southern England are discussed. The noise in a band of width 300 cps over the frequency range 10–35 kc is found to be intermediate in nature between fluctuation noise and discrete pulses, the ratio of the rms value of the envelope to the average value being about 5, compared with 1.1 for fluctuation noise. A detailed analysis of the noise is made in terms of the amplitude distribution of the peaks in the envelope and the amplitude probability distribution of the envelope itself. These distributions can be interrelated at the higher voltage levels, where the pulses have consistent shape determined by the receiver characteristics. The stronger pulses are randomly distributed in time while the weaker ones tend to occur in groups.

551.594.6:621.396.9 446
The Location of Thunderstorms by a Single-Station High-Frequency Ranging Technique—C. Clarke and B. J. Byrne. (*J. Atmos. Terr. Phys.*, vol. 9, pp. 210–228; October, 1956.) Continuation of work reported by Horner (1065 of 1954); the influence of ionospheric conditions on the observations is investigated in greater detail. Outside the sunset and sunrise periods, the E- and F_1-layer conditions can be calculated sufficiently accurately from the zenithal angle of the sun; the F_2-layer conditions are derived from the predicted critical frequencies and muf factors. Range measurement appears to be impossible when propagation is controlled by the E_s layer. Observations made during the summer of 1954 are compared with thunderstorm positions given by a direction-finder network. The results indicate that the single-station technique can be expected to be satisfactory for locating thunderstorms at a distance of 500–2000 km for about 70 per cent of the time.

551.594.5 447
The Polar Aurora [Book Review]—C. Størmer. Clarendon Press, Oxford, and University Press, London, 403 pp., 55s. 1955. (*Nature, Lond.*, vol. 178, p. 713; October 6, 1956.) An authoritative study in the series of International Monographs on Radio. Chapters are included on auroral rf radiation and on radio echoes from aurora.

LOCATION AND AIDS TO NAVIGATION

621.396.93:621.396.674.3 448
The Use of a Horizontal Dipole as a Direction-Finding Antenna—Millington. (See 345.)

621.396.93:621.396.677 449
Possible Errors of a Particular Wide-Aperture Direction Finder—W. C. Bain. (*Proc. IEE*, Part C, vol. 103, pp. 313–324; September, 1956.) "A study is made of the extent to which the high-frequency cyclical direction-finder devised by Earp Godfrey [1059 of 1949] is subject to three common types of error. First, the result is presented of theoretical computations on the errors given by a practical fixed-antenna system in wave-interference conditions. The variance of these errors as the phase difference between the incident rays is varied is shown to be the same as that given by the ideal rotating-antenna version of this direction-finder; it is appreciably smaller than that of an Adcock for a system aperture of 4λ, and, in general, much smaller for an aperture of 10λ. Secondly, errors due to antenna interaction are considered for a system of 24 unipoles, 9 m high and 1.1 m in diameter, placed on a circle of 100 m diameter. It is concluded that the errors in indicated bearing are likely to be negligible, provided that the antennas not in use at any instant are terminated by a resistor equal to their nominal characteristic impedance. Finally, the polarization error is examined for such a system in which surface feeders are used, without an earth mat, on ground of moderate conductivity; it is found to be small, being greatest at the low-frequency end of the band, where the standard-wave error is about 1° at 3 mc. With extended feeders the errors at low frequencies are reduced considerably."

621.396.93:621.396.677.6 450
H.F. Bearing Variations on an Adcock Direction-Finder—E. N. Bramley. (*Proc. IEE*, Part C, vol. 103, pp. 350–356; September, 1956.) "Measurements on a number of transmitters at ranges from 1000 to 5000 km show that the variance of snap bearings within a period of half an hour is of the order of 10 deg². To reduce this variance by a factor of ten, time averaging over about 5 min is required when the bearings are taken at 10-sec intervals. Bearing changes from hour to hour and from day to day have a variance of about 1 deg² and thus set a limit to the error reduction obtainable by averaging over a half-hour period. The results are consistent with previously published estimates of bearing variances."

621.396.93:621.396.677.6 451
The Calibration of a 6-Mast Adcock Array—K. Baur. (*Nachrichtentech. Z.*, vol. 9, pp. 299–305; July, 1956.) A raised test transmitter in the vicinity of the array provides a beam of the desired oblique incidence but also causes a complex bearing error due to beam divergence. The real part of this error consists of the natural system error for plane-polarized waves, modified by a divergence error, and the imaginary part determines the blurring effect. A minimum divergence error, irrespective of ground conditions, is obtained for an angle of elevation of 40° and the error may be neglected where the transmitter distance exceeds $15a$, where a is the distance between opposite masts.

621.396.96 452
Marine Radar Developments—(*Wireless World*, vol. 62, pp. 585–586; December, 1956.) Two new developments in British commercial equipment are described. The "true-motion" display is obtained by deriving a voltage which is used to shift the origin of the ppi display in accordance with the ship's motion. The other development is the use of a slotted-waveguide antenna and printed circuits in a compact, reliable, low-cost equipment.

621.396.963.3 453
Radar Simulator for Laboratory Use—H. J. Bickel and R. I. Bernstein. (*Electronics*, vol. 29, pp. 170–173; October, 1956.)

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.7:621.316.825 454
Investigation of the Use of Thermistors for the Measurement of Low Pressures—M. Varićak. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 893–895; September 24, 1956.) Theory indicates that the sensitivity of thermistor vacuum gauges is increased by making the wall temperature low and the thermistor surface area large. Observations of the time variation of the voltage across bead thermistors passing a current of 1 ma following a sudden change of pressure from 10^{-5} to 10^{-3} mm Hg at wall temperatures of 203° and 293°K confirm the theory. The time taken to attain thermal equilibrium is 5 min. On increasing the heat-dissipating surface by placing a piece of tinfoil in contact with the thermistor both the response time and the sensitivity are greatly improved. Pressures down to 10^{-6} mm Hg can be measured.

535.37:539.154 455
The Effect of Nuclear Radiation on the Optical Properties of Inorganic Phosphors—F. Bandow. (*Optik, Stuttgart*, vol. 13, pp. 259–263; 1956.) Effects produced by α rays are summarized.

537.37:[546.472.21+546.47–31 456
Connection between the Catalytic Properties and the Luminescence of Zinc Oxide and Zinc Sulphide—L. N. Shekhter, I. A. Myasnikov, and S. Ya Pshezhetski. (*C. R. Acad. Sci. U.R.S.S.*, vol. 109, pp. 1163–1166; August 21, 1956. In Russian.)

535.37:546.472.21 457
Electron Traps at Very Low Energy Levels in ZnS—N. Riehl and H. Ortmann. (*Z. Naturf.*, vol. 10a, pp. 896–897; November, 1955.) Observations made at temperatures below that of liquid air are briefly reported. A very sharp peak in the glow curve is exhibited between 63° and 93°K.

537.226/.227 458
Ferroelectricity in the Langbeinite System—F. Jona and R. Pepinsky. (*Phys. Rev.*, vol. 103, p. 1126; August 15, 1956.) Preliminary note on an investigation of $(NH_4)_2Cd_2(SO_4)_3$ crystals.

537.226/.227 459
Nonlinear Properties of Ferroelectrics at High Field Strengths—A. L. Khodakov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 51–60; January, 1956.) The dependence on field strength of the permittivity and the loss tangent of solid solutions involving $BaTiO_3$ was investigated experimentally. The strong effect of the firing condi-

tions of the ceramic on its nonlinear properties was established; these properties appear at temperatures above the Curie point. Curves of the ac permittivity are plotted, as are also curves of the variation of the differential permittivity during one period, obtained by oscillograph. The maxima of the latter curves at saturation are almost independent of the value of the applied constant field, and occur at a definite instantaneous value of the alternating field.

537.226/.227:546.431.824–31 460

Dielectric Properties of Certain Solid Solutions Containing Barium Titanate—N. S. Novosil'tsev and A. L. Khodakov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 310–322; February, 1956.) A detailed report is presented, with numerous curves and tables, on an experimental investigation of the temperature variation of the permittivity, losses, and conductivity of various solid solutions. The temperature range within which the tetragonal phase exists can be extended or reduced by the suitable choice of constituents.

537.226/.227:546.431.824–31 461

Effect of Pile Irradiation on the Dielectric Constant of Ceramic $BaTiO_3$—F. T. Rogers, Jr. (*J. Appl. Phys.*, vol. 27, pp. 1066–1067; September, 1956.) A peak in the dielectric-constant/temperature curve, usually associated with ferroelectricity, was greatly attenuated after irradiation and the dielectric constant assumed a much reduced value, nearly constant over the range 30°–140°C.

537.226/.227:547.476.3 462

On the Domain Structure of Rochelle Salt Crystal—T. Nakamura. (*J. Phys. Soc. Japan*, vol. 11, pp. 624–632; June, 1956.) Slow crystallization at temperatures between two Curie points gave domains parallel to the *b*-axis; crystallization at temperatures above the upper Curie point gave domains parallel to the *c*-axis. Domain width remains unchanged with rising temperature until the pattern disappears at 24.25°C ±0.2°. Domain formation appears to be governed by elastic rather than by electrostatic factors.

537.226/.228:546.431.824–31 463

The Preparation of Barium Titanate as a Ceramic Transducer Material—A. L. Gray and J. M. Herbert. (*Acustica*, vol. 6, pp. 229–234; 1956.) "Modified barium titanate ceramics can be prepared with reduced temperature coefficients at room temperature. Values of coercive field and dielectric loss which permit the operation of transducers up to the onset of cavitation in liquids can be obtained The mechanical and electrical properties of the modified ceramics change significantly with time but the drift can be minimized. Transducers of suitable shapes can be made by a variety of methods."

537.226/.228:546.431.824.831–31 464

Structural Transitions in Barium Titanate-Zirconate Transducer Materials—R. C. Kell and N. J. Hellicar. (*Acustica*, vol. 6, pp. 235–238; 1956.) The properties of ceramic materials having compositions with Ti:Zr ratios between 100:0 and 70:30 are described. A material with a Ti:Zr ratio of 95:5 is most suitable for transducers; this has an orthorhombic phase which is stable between 5° and 50°C, and the change in resonance frequency over this range is only 4 per cent.

537.226/.228.2 465

Determination of the Electrostriction Constant Q_{11} of Barium Titanate Ceramic—G. Schmidt. (*Z. Phys.*, vol. 145, pp. 534–542; June 15, 1956.) The constant was determined from measurements of the thickness variations and polarization of disks oscillating at low frequency, at temperatures between 20° and 150°C. Its value is about 0.6×10^{-12} cgs units within the Curie region, and somewhat more at higher temperatures; there is a pronounced minimum at the Curie point.

537.226/.228.1 466

The Effect of Impurities on the Permittivity and Piezoelectric Modulus of Rochelle Salt—T. Kh. Chormonov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 323–326; February, 1956.) Rochelle-salt crystals were grown with impurities (aluminium alums, copper sulphate, and rubidium, lithium, and strontium chlorides). Curves show the effects on the electrical properties.

537.311.31:538.221 467

Electrical Resistance of Ferromagnetic Metals—T. Kasuya. (*Progr. Theor. Phys.*, vol. 16, pp. 58–63; July, 1956.) Theoretical and experimental results indicate that the anomalous resistivity associated with the ferromagnetic properties can be explained by the dependence of the exchange energy between the conduction electrons and those of the unfilled inner shell on the relative direction of the electron spins.

537.311.33 468

Intrinsic Electronic Conduction in Semiconductors—K. W. Böer. (*Z. Naturf.*, vol. 10a, pp. 898–899; November, 1955.) Under conditions of true intrinsic conduction, the current-carrier concentration and mobility can be calculated from the measured conductivity. Results which have been obtained in this way for various semiconductors are smaller by some orders of magnitude than values obtained by Hall-effect and other measurements. A family of conductivity/temperature curves for CdS shows the existence of limit curves for high and low rates of heating. Considering the observations on the basis of lattice imperfections, it is concluded that only for very rapid heating will the measured conductivity agree with the values calculated purely from analysis of the electron system; the type of conduction occurring is not in fact intrinsic but may be termed "intrinsic impurity."

537.311.33 469

Thermomagnetic and Galvanomagnetic Effects in Semiconductors taking Account of the Variation of the Carrier Concentration—G. E. Pikus. (*Zh. Tekh. Fiz.*, vol. 26, pp. 22–35, 36–50; January, 1956.) A mathematical discussion is presented in two parts. In the first part, the effects in semiconductors with current carriers of both types are considered for small variations of the concentration of electron-hole pairs, *i.e.*, in weak fields. The second part deals with the case of strong fields, when the concentration of the carrier pairs differs considerably from the equilibrium value. The effect of the concentration variations on the electron and exciton thermal conductivities is also discussed.

537.311.33 470

The Recombination of Electrons and Holes in the Presence of Traps of Various Types—S. G. Kalashnikov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 241–250; February, 1956.) The stationary case, with a low concentration of nonequilibrium carriers, is considered. The degree of filling of traps of any type depends on the presence of other types, hence the probabilities of recombination caused by traps of various types are not in general additive. The case is considered where the concentration of centers of one type is high. Under certain conditions, the existence of such centers may greatly affect the lifetime of nonequilibrium carriers, although the centers themselves may not affect the recombination or the conductivity of the semiconductor.

537.311.33 471

The Effect of a Strong Field in Semiconductors—Yu. K. Pozhela. (*Zh. Tekh. Fiz.*, vol. 26, pp. 277–280; February, 1956.) It was established by A. V. and A. F. Ioffe (*Zh. Eksp. Teor. Fiz.*, vol. 9, pp. 1428–1458; 1939.) that if the field applied to a semiconductor exceeds a critical value, a sharp increase in the current is observed. This can only be explained by an increase in the number of current carriers Various possible explanatory mechanisms are discussed; the additional carriers may be produced by a transfer of electrons from the valence band to the conduction band. Observations of the drift of the additional carriers confirming the theory are reported in a separate paper (*ibid.*, pp. 281–283).

537.311.33 472

The Emission Capacity of an Abrupt *p-n* Junction and its Effect on the Conductivity of a Semiconductor—K. B. Tolpygo. (*Zh. Tekh. Fiz.*, vol. 26, pp. 293–309; February, 1956.) An approximate solution is obtained of equations describing the forward flow of current at a semiconductor-junction barrier layer. It is assumed that both acceptor and donor levels are almost completely ionized and that the width of the region of variable impurity concentration is smaller than or of the order of the screening length. Estimates are made of 1) current distributions and concentrations of electrons and holes as functions of the total current and the properties of the junction, and 2) conditions necessary for the current to be carried by minority carriers.

537.311.33:537.312.8 473

D.C. Magnetoconductivity and Energy-Band Structure in Semiconductors—R. M. Broudy and J. D. Venables. (*Phys. Rev.*, vol. 103, pp. 1129–1130; August 15, 1956.) An experimental method suitable for the direct evaluation of the components of the magneto-conductivity tensor is described.

537.311.33:546.23 474

The Electrical Conductivity of Hexagonal Selenium—R. A. Hyman. (*Proc. Phys. Soc.*, vol. 69, pp. 743–747; July 1, 1956.) It is suggested that the crystal is formed on continuous chains of atoms which zig-zag so as to fill a volume large compared with the lattice spacing; it is assumed that charge carriers (holes) move freely along these chains, but transitions between chains are difficult. The calculated dependence of conductivity on frequency and the rise of mobility with temperature are in agreement with actual values, but the magnitude of the resistivity is not yet explained. Bending of single crystals is also discussed briefly in a separate paper (*ibid.*, pp. 771–772).

537.311.33:546.24:538.63 475

Galvanomagnetic Properties and Hole Conductivity of Tellurium—S. S. Shalyt. (*C.R. Acad. Sci. U.R.S.S.*, vol. 109, pp. 705–752; August 1, 1956. In Russian.) An experimental investigation at temperatures of 77.4°, 4.2°, and 1.3°K is reported; results, which are presented graphically, indicate the presence of two groups of holes with different mobilities.

537.311.33:546.26–1 476

Cyclotron Resonance Effects in Graphite—J. K. Galt, W. A. Yager, and H. W. Dail, Jr. (*Phys. Rev.*, vol. 103, pp. 1586–1587; September 1, 1956.) Report of effects observed in crystalline flakes of graphite at 77°, 4.2°, 1.3°, and 1.1°K, at a frequency of 24 kmc. A tentative interpretation of the observations is given.

537.311.33:[546.28+546.289 477

Theory of Cyclotron Resonance Absorption in Many-Valley Semiconductors—L. Gold, W. M. Bullis, and R. A. Campbell, (*Phys. Rev.*, vol. 103, pp. 1250–1252; September 1, 1956.) Theory is presented which allows for energy dependence of scattering time in Ge and Si.

537.311.33:546.28 478

Application of the Orthogonalized-Plane-Wave Method to Silicon Crystal—T. O.

Woodruff. (*Phys. Rev.*, vol. 103, pp. 1159–1166; September 1, 1956.)

537.311.33:546.28 479

Line Broadening of an Impurity Spectrum in Silicon—D. Sampson and H. Margenau. (*Phys. Rev.*, vol. 103, pp. 879–885; August 15, 1956.) A simplification of the method of calculation presented by Lax and Burstein (1086 of 1956).

537.311.33:546.28 480

Nuclear Magnetic Resonance of Si^{29} in *n*- and *p*-Type Silicon—R. G. Shulman and B. J. Wyluda. (*Phys. Rev.*, vol. 103, pp. 1127–1129; August 15, 1956.)

537.311.33:546.281.26 481

The Effect of Impurities on the Electrical Conductivity and Nonlinearity of Silicon Carbides—L. I. Ivanov and V. I. Pruzhinina-Granovskaya. (*Zh. Tekh. Fiz.*, vol. 26, pp. 220–231; January, 1956.) A method is described for determining the nonlinearity and resistance of powder semiconductors, and the dependence of these two parameters on the granular composition of the powders and on the pressure is discussed. Experiments have shown that impurities greatly affect the properties of silicon carbides.

537.311.33:546.289 482

Visual Evidence of Inversion Layers on Semiconductor Materials—P. Levesque. (*J. Appl. Phys.*, vol. 27, pp. 1104–1105; September, 1956.) Observations on etched Ge specimens, made by a technique involving deposition of a $BaTiO_1$ layer, are briefly reported.

537.311.33:546.289 483

An Investigation of the Resistance Variation of Germanium in a Magnetic Field—V. I. Stafeev and V. M. Tuchkevich. (*Zh. Tekh. Fiz.*, vol. 26, pp. 273–276; February, 1956.) The experimental curves $\Delta\rho/\rho_0$ vs magnetic field for different temperatures show that the variation is nonlinear both for strong and weak fields, the power indices depending on temperature. At relatively low temperatures, of the order of 170°K, $\Delta\rho/\rho_0$ varies more slowly than the square of the mobility. These findings are at variance with existing theory. For all *p*-type specimens the temperature variation curve exhibits a maximum, as predicted by theory.

537.311.33:546.289 484

The Diffusion of Impurities in Germanium—B. I. Boltaks. (*Zh. Tekh. Fiz.*, vol. 26, pp. 457–474; February, 1956.) A comprehensive review of the experimental data, divided into the following sections: 1) methods for measuring the diffusion coefficients in semiconductors; 2) diffusion and electrical activity of impurities in Ge; 3) temperature dependence of the diffusion coefficients of impurities in Ge, and 4) diffusion and solubility of impurities in Ge. A close connection between the diffusion and solubility of impurities and the electrical properties of Ge is indicated. The diffusion and solubility exhibit a number of important peculiarities which do not exist in metals and alloys. 48 references.

537.311.33:546.289 485

Field-Induced Conductivity Changes in Ge—H. C. Montgomery and W. L. Brown. (*Phys. Rev.*, vol. 103, pp. 865–870; August 15, 1956.) Measurements were made on filament specimens with fields of strength up to 10^5V/cm normal to the surface. From observations of the minimum in the conductance curve, information can be derived on surface states as a function of surface potential. Data obtained using various gaseous ambients are compared with the contact-potential observations of Brattain and Bardeen (1698 of 1953). Measurements at temperatures down to 170°K give information about properties of "fast" surface states. Phase-shift loops observed at frequencies around 1 kc are interpreted in terms of minority-carrier lifetime.

537.311.33:546.289 486

Acceptors Quenched into Germanium—S. Mayburg. (*Phys. Rev.*, vol. 103, pp. 1130–1131; August 15, 1956.) Discrepancies between results obtained previously by the author (148 of 1955) and other workers [1765 of 1956 (Hopkins and Clarke) and 2793 of 1956 (Logan)] are explained by taking note of dislocation effects.

537.311.33:546.289 487

Use of Infrared Absorption in Germanium to determine Carrier Distributions for Injection and Extraction—N. J. Harrick. (*Phys. Rev.*, vol. 103, pp. 1173–1181; September 1, 1956.) Continuing the work reported previously (2109 of 1956), measurements of infrared absorption have been used to determine longitudinal distributions of free carriers for the cases of field-opposed and field-aided injection and extraction.

537.311.33:546.289 488

Elastogalvanomagnetic Effect and Intervalley Scattering in *n*-Type Germanium—R. W. Keyes. (*Phys. Rev.*, vol. 103, pp. 1240–1245; September 1, 1956.) "Starting from a multivalley model of a cubic semiconductor, a calculation of the effect of elastic strain on certain galvanomagnetic effects is carried out. It is found that the effects are sensitive to the strength of the intervalley scattering. An experiment on Ge to which the calculation is applicable is described. It is concluded from a comparison of the theory and the experiment that the coupling constant which characterizes the coupling of the electrons to the intervalley phonons in the model of Herring [2642 of 1955] is considerably smaller than the coupling constant to the acoustic phonons.

537.311.33:546.289 489

Carrier Accumulation in Germanium—J. B. Arthur, A. F. Gibson, and J. B. Gunn. (*Proc. Phys. Soc.*, vol. 69, pp. 697–704; July 1, 1956.) An account is given of experiments on junctions between lightly and heavily doped regions of crystals of the same conductivity type; these are designated L-H junctions. They can be made largely impermeable to minority carriers but permeable to majority carriers, and high concentrations of minority carriers can be accumulated at such junctions.

537.311.33:546.289 490

Current Gain at L-H Junctions in Germanium—J. B. Arthur, A. F. Gibson, and J. B. Gunn. (*Proc. Phys. Soc.*, vol. 69, pp. 705–711; July 1, 1956.) The relatively low permeability to minority carriers of junctions between lightly and heavily doped crystals of the same type (see 489 above) can be considered as a reduction of the minority carrier mobility, and gives rise to enhanced current gain in certain structures, for example filamentary transistors. Experiments confirming the existence of the effect and indicating its magnitude are described.

537.311.33:546.289:535.215:538 639 491

The Transverse Photomagnetic Effect in *n*- and *p*-Type Germanium—I. K. Kikoin and Yu. A. Bykovski. (*C.R. Acad. Sci. U.R.S.S.*, vol. 109, pp. 735–736; August 1, 1956. In Russian.) The effect investigated is the following: if a semiconductor in a magnetic field H, with components H_x and H_y in the x and y directions, is illuminated by light in the direction of the y axis, then in addition to the emf proportional to H along the z axis an emf is produced in the x direction proportional to H_xH_y. The emf E is plotted against H for *p*-type Ge at temperatures of +20°, −20°, and −100°C, and against temperature for *p*- and *n*-type Ge at $H = 20000$ oersted.

537.311.33:546.482.21 492

Redistribution of the Electron Density in Cadmium Sulphide Crystals associated with Changes in its Electrical Conductivity—Yu. N. Shuvalov. (*C.R. Acad. Sci. U.R.S.S.*, vol. 109 pp. 753–756; August 1, 1956. In Russian.) Results of an X-ray investigation of hexagonal crystals are reported.

537.311.33:546.682.19 493

The Electrical Properties of InAs—D. N. Nasledov and A. Yu. Khalilov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 251–254; February, 1956.) An investigation was made over the temperature range 1.3°–673°K and in magnetic fields up to 33,000 oersted. The main results are as follows: 1) conductivity is practically independent of temperature from 1.3°K to room temperature; above this temperature it rapidly increases; 2) the concentration of carriers at room temperature is about $10^{17}/cm^3$; 3) in a magnetic field of 20,000 oersted, resistance increases fourfold at 400°C; 4) mobility increases greatly at high temperatures and reaches 120,000 cm per V/cm.

537.311.33:546.682.86 494

Electrical Properties of InSb—D. N. Nasledov and A. Yu. Khalilov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 6–14; January, 1956.) Specimens with *n*- and *p*-type conductivity were investigated over a range of temperatures from 1.3° to 673°K. Curves show the variation of conductivity with temperature and the effect of a magnetic field of strength 20,000 oersted. The Hall effect was also investigated for various compositions, using magnetic field intensities up to 33,000 oersted. A theoretical interpretation of the results is given.

537.311.33:546.682.86 495

Indirect Transitions in Indium Antimonide—R. F. Potter. (*Phys. Rev.*, vol. 103, pp. 861–862; August 15, 1956.) "An interpretation of published infrared absorption data for InSb is made. It is proposed that the absorption beyond the main optical edge is due to indirect transitions involving both optical mode and low-energy acoustical mode phonons."

537.311.33:546.817.221 496

Calculation of the Cohesive Energy of Zincblende—S. Asano and Y. Tomishima. (*J. Phys. Soc. Japan*, vol. 11, pp. 644–653; June, 1956.)

537.311.33:546.817.221:539.234 497

Surface Structure of Thin Layer of PbS obtained by Evaporation in Vacuum—R. Ya. Berlaga, M. I. Rudenok, and L. P. Strakhov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 3–5; January, 1956.)

537.311.33:621.396.822 498

Shot Noise in Semiconductors—L. Ya. Pervova. (*Radiotekhnika i Elektronika*, vol. 1, pp. 98–105; January, 1956.) An expression is derived for the spectral density of shot noise in an arbitrary length of semiconductor taking into account the true lifetimes, τ, of electrons in the conduction zone (instead of the average lifetime) and the length L of the semiconductor. For $\gamma \ll L$, where γ is the free path of the electron, the noise spectral density is proportional to $1/\omega$ in the range $\omega\tau \simeq 1$ to $\omega\tau \approx 10^3$; for $\omega\tau < 1$, the noise intensity is independent of frequency, for $\omega\tau > 10^3$ the noise varies as $1/\omega^2$. For $\gamma > L$ the spectral density remains nearly constant up to $\omega\tau \approx \lambda/L$, and is proportional to $1/\omega$ for $\omega\tau > \lambda/L$.

538.22 499

The Magnetic Properties of $FeSe_x$ with NiAs Structure—T. Hirone and S. Chiba. (*J. Phys. Soc. Japan*, vol. 11, pp. 666–670; June, 1956.) In the range 48.8 per cent–53.1 per cent Se, at room temperature, the compound is made up of two phases, α and β; the α phase

has PbO structure and is weakly paramagnetic or antiferromagnetic, while the β phase has NiAs structure and is ferrimagnetic.

538.221 500

A Symposium on Magnetism.—London, September 1955—A. C. Lynch and J. Watkins. (*Brit. J. Appl. Phys.*, vol. 7, pp. 236–242; July, 1956.) Summaries are presented of papers and discussion on theoretical studies and applications, particularly of ferrites, and including the use of neutron diffraction techniques.

538.221 501

Curvature of the Bloch Wall as an Elementary Process in Reversible Variations of Magnetization (Initial Permeability and ΔE-Effect)—M. Kersten. (*Z. Angew. Phys.*, vol. 8, pp. 313–322; July, 1956.) The observed temperature variations of initial permeability and ΔE-effect can be explained if cylindrical rather than cushion-type or spherical walls are assumed.

538.221 502

The Magnetic Properties of Chromium-Tellurium-Selenium Systems—I. Tsubokawa. (*J. Phys. Soc. Japan*, vol. 11, pp. 662–665; June, 1956.) Properties of compounds having the formula $Cr(Te_{1-3}Se_x)$ are discussed. They are ferromagnetic in the range $0<x<0.8$; outside this range they are paramagnetic or antiferromagnetic.

538.221 503

Effect of Magnetic Field Strength during Condensation on the Coercivity and Form of Vapour-Deposited Iron—A. J. Griest, J. F. Libsch, and G. P. Conard. (*J. Appl. Phys.*, vol. 27, pp. 1022–1024; September, 1956.) The size, shape, and coercivity of Fe particles deposited from vapor on to a Cu surface were all influenced by the temperature of condensation and the strength of the applied magnetic field. The coercivity increased with the field strength, but the amount of the increase decreased as the condensation temperature was raised. The observed coercivity values of 30–120 oersted were related to strain in the deposited material.

538.221:621.318.122 504

Magnetic After-Effect in Ni_2Mn Alloy—T. Taoka. (*J. Phys. Soc. Japan*, vol. 11, pp. 537–547; May, 1956.) Continuation of work described previously [2042 of 1955 (Taoka and Ohtsuka)]. Experimental results are reported in detail. An electron-microscope study confirms that alloys showing marked after-effect consist of numerous single-domain particles of prolate ellipsoidal form embedded in a matrix.

538.221:621.318.122 505

Study of Magnetic Annealing on Ni_3Fe Single Crystal—S. Chikazumi. (*J. Phys. Soc. Japan*, vol. 11, pp. 551–558; May, 1956.)

538.221:621.318.124 506

Investigations on Barium Ferrite Magnets—K. J. Sixtus, K. J. Kronenberg, and R. K. Tenzer. (*J. Appl. Phys.*, vol. 27, pp. 1051–1057; September, 1956.) Report of an experimental investigation of the relation between sintering temperature, particle size and coercive force in $BaO{:}6Fe_2O_3$. With particles of linear dimensions $>10^{-3}$ cm, domain-wall movements are observed on application of a magnetic field; for dimensions $<5\times10^{-4}$ cm the observations indicate reversals of magnetization by the rotation process. With particles of intermediate size, both processes occur.

538.221:621.318.13 507

Some Properties of the Coercive Force in Soft Magnetic Materials—D. S. Rodbell and C. P. Bean. (*Phys. Rev.*, vol. 103, pp. 886–895; August 15, 1956.) A discussion in terms of domain-wall movements indicates that the coercive force is composed of two terms, one characteristic of the bulk material and the other arising from the pinning of domain walls at the surfaces. The observed increase in coercive force with decrease in thickness of sheet specimens is thus explained. See also 1126 of 1956.

538.221:621.318.13.014.4 508

The Eddy-Current Anomaly in Electrical Sheet Steel—H. Aspden. (*Proc. IEE*, Part C, vol. 103, pp. 272–278; September, 1956.) "A theory which accounts for the well-known discrepancy between predicted eddy-current losses in electrical sheet steels and the experimentally observed values is presented. The anomaly is shown to be due partly to the magnetic inhomogeneity arising from ferromagnetic domain structure and partly to a time-lag effect caused by the finite speed of domain boundary movements. A new experimental approach to the study of the eddy-current anomaly is described. This involves the use of a method of measuring the anomaly factor as it applies instantaneously at a point in a magnetization cycle."

538.221:621.318.13.014.4 509

Magnetic Time-Lag Effects in Solid Steel Cores—H. Aspden. (*Proc. IEE*, Part C, vol. 103, pp. 279–285; September, 1956.) The discrepancy between theoretical and actual eddy-current effects in thick steel cores is found to be attributable to time-lag in the magnetization process, the magnitude of which decreases with increasing frequency, its value being about 10^{-5}s at 10 kc.

538.221:621.318.134 510

Cation Distributions in Ferrospinels. Theoretical—H. B. Callen, S. E. Harrison, and C. J. Kriessman. (*Phys. Rev.*, vol. 103, pp. 851–856; August 15, 1956.) The thermodynamic relation between the ion distribution and the nonthermal part of the internal energy function is developed. The results are used in a separate paper [*ibid.*, pp. 857–860 (Kriessman and Harrison)] to interpret observations on Mg-Mn ferrites.

538.221:621.318.134 511

On the Uniaxial Anisotropy Induced by Magnetic Annealing in Ferrites—S. Taniguchi and M. Yamamoto. (*J. Phys. Soc. Japan*, vol. 11, pp. 604–605; May, 1956.)

538.221:621.318.134:621.372.8 512

Relations between the Structure of Ferrites and Conditions for Their Resonance in Waveguides. Unidirectional Guides—J. Suchet. (*Onde Élect.*, vol. 36, pp. 508–519; June, 1956.) An examination is made of the influence on the behavior of ferrites of their composition and method of preparation, and the unidirectional propagation characteristics of waveguides enclosing Ni-Zn and Ni-Al ferrites are calculated.

548.0 513

Observations of Dislocation Glide and Climb in Lithium Fluoride Crystals—J. J. Gilman and W. G. Johnston. (*J. Appl. Phys.*, vol. 27, pp. 1018–1022; September, 1956.)

621.315.61+621.318.1+621.315.3 514

Materials for Electronics—J. Markus and D. A. Findlay. (*Electronics*, vol. 29, pp. 185–216; October, 1956.) A survey of U. S. products, including insulating and magnetic materials, wires, and solders.

621.315.612.6 515

Thermal Expansion of Binary Alkali Silicate Glasses—H. F. Shermer. (*J. Res. Nat. Bur. Stand.*, vol. 57, pp. 97–101; August, 1956.)

621.315.616:[537.531.9+539.166.9 516

Radiation-Induced Conductivity in Polyethylene and Teflon—R. A. Meyer, F. L. Bouquet, and R. S. Alger. (*J. Appl. Phys.*, vol. 27, pp. 1012–1018; September, 1956.) Conductivity changes induced by bombardment with X rays and gamma rays have been studied as a function of time, temperature, specimen geometry, exposure rate, and applied electric field. Observed photocurrents were directly proportional to exposure rate and field. The conductivity increased by a factor of about 10^3 during irradiation and the photocurrent was nearly independent of temperature over the range 78°–273°K.

MATHEMATICS

517 517

Incomplete Bessel and Struve Functions—W. H. Steel and J. Y. Ward. (*Proc. Camb. Phil. Soc.*, vol. 52, pp. 431–441; July, 1956.) "Some properties are given of the incomplete Bessel and Struve functions defined by a Poisson-type integral. These functions are tabulated for the orders 0 and 1."

517:518.2 518

Laguerre Functions: Tables and Properties—J. W. Head and W. P. Wilson. (*Proc. IEE*, Part C, vol. 103, pp. 428–440; September, 1956.) "The first 21 Laguerre functions have been tabulated to four decimal places (or two significant figures when this is more accurate) for values of the argument 0(0.1)1(0.2)3(0.5)6(1)14(2)40(5)100. The practical applications of these functions are briefly considered. The zeros of these Laguerre functions are also tabulated to 5 places, the last of which is not reliable except in the case of the smallest zero for orders above 6. Differentiation and integration of Laguerre functions, orthonormal properties and addition formulas are briefly discussed. Finite or infinite series of Laguerre functions whose sums are well-known functions such as products of polynomials and circular or exponential functions, step and delta functions, Bessel and Kelvin functions, and gamma and error functions are stated."

512.9 519

Champs de Vecteurs et de Tenseurs [Book Review]—E. Bauer. Masson; Paris, 204 pp., 2200 fr. (*Phil. Mag.*, vol. 1, p. 691; July, 1956.) A straightforward account of vectors, tensors and electromagnetism, in a form ready for application to engineering problems.

517 520

Numerical Analysis [Book Review]—Z. Kopal. Chapman and Hall, London, 556 pp., 63s. 1955, (*Brit. J. Appl. Phys.*, vol. 7, pp. 269–270; July, 1956.) A comprehensive handbook; emphasis is on the application of numerical techniques to problems of infinitesimal calculus in a single variable.

MEASUREMENTS AND TEST GEAR

621.314.7.001.4(083.74) 521

IRE Standards on Solid-State Devices: Methods of Testing Transistors, 1956.—(Proc. IRE, vol. 44, pp. 1542–1561; November, 1956.) Standard 56 I.R.E. 28. S2.

621.317.3.029.6:621.372.5 522

Microwave Measurements with a Lossy Variable Termination—H. M. Altschuler and A. A. Oliner. (*Proc. IEE*, Part C, vol. 103, pp. 392–399; September, 1956.) The problem is treated by considering the lossy termination as the combination of a purely lossy quadripole ("reflection-coefficient transformer") with a loss-free termination. The measurement data can then be analyzed as for the familiar case of an actual loss-free termination.

621.317.32:537.525.8 523

"Glo-Ball" Development—J. F. Steinhaus. (*Rev. Sci. Inst.*, vol. 27, pp. 575–580; August, 1956.) The "glo-ball" is a thin-walled partially evacuated glass sphere containing helium, used for investigating electric field distributions in resonant cavities; spheres with diameters ranging between $\frac{1}{4}$ inch and 1 inch have been used in studying linear accelerators. The indication of the field strength is given by ionization of the

gas in the device. Technique for producing "glo-balls" with stable and relatively low ionization thresholds is discussed.

621.317.382:621.317.784:538.632:537.311.33 524

The Application of the Hall Effect in a Semiconductor to the Measurement of Power in an Electromagnetic Field, and the Design of Semiconductor Wattmeters for Power-Frequency and Audio-Frequency Applications—H. E. M. Barlow. (*Proc. IEE*, Part B, vol. 103, p. 710; November, 1956.) Discussion on 1735 and 1744 of 1955.

621.317.431 525

Magnetic-Switch B/H Loop Tracer—W. Geyger. (*Electronics*, vol. 29, pp. 167–169; October, 1956.) Magnetic switching of Si-diode chopper circuits enables dynamic hysteresis loops to be traced at frequencies up to 20 kc.

621.317.444:550.380.8 526

High-Altitude Measurements of the Earth's Magnetic Field with a Proton Precession Magnetometer—L. J. Cahill, Jr, and J. A. Van Allen. (*J. Geophys. Res.*, vol. 61, pp. 547–558; September, 1956.) An instrument of the Packard-Varian type (*Phys. Rev.*, vol. 93, p. 941; February 15, 1954), has been used for measurements at heights up to 100,000 ft. The equipment, including magnetic head, amplifier, and telemetering transmitter, is carried by a plastic balloon. The results indicate that the field strength decreases with increasing height, and that there are large variations with geographical position. An instrument that can be carried to a height of 150 km by rocket has been constructed.

621.317.7:621.373.4 527

Phase Generator for Tropospheric Research—R. W. Hubbard and M. C. Thompson, Jr. (*Electronics*, vol. 29, pp. 220–223; October, 1956.) A laboratory-standard instrument based on earlier work [*Rev. Sci. Instr.*, vol. 26, pp. 617–618; June, 1955 (Thompson)], gives pulsed or sinusoidal signals with phase displacements up to 360° in steps of 2°.

621.317.7.082.64:621.316.86 528

The Indirectly Heated Thermistor as a Precise A.C.-D.C. Transfer Device—F. C. Widdis. (*Proc. IEE*, Part B, vol. 103, pp. 693–703. Discussion, pp. 707–709; November, 1956.) Methods are described for eliminating thermal drift in indirectly heated thermistors used as transfer devices for measurements of voltages and currents, thus rendering the device suitable for precision use over a wide range of audio frequencies. The sensitivity is high, but this advantage is to some extent outweighed by the slow response. dc reversal errors due to Peltier and Thomson effects are small.

621.317.733:621.317.335.3 529

A Bridge for the Measurement of Permittivity—A. M. Thompson. (*Proc. IEE*, Part B, vol. 103, pp. 704–707. Discussion, pp. 707–709; November, 1956.) "The direct admittance of a 3-terminal capacitor with the sample as dielectric is measured as a complex capacitance, the two components being indicated directly on two 3-terminal variable air capacitors. In addition to these the bridge network comprises transformer ratio-arms and an amplifier whose output voltage is in quadrature with that of the transformer. The bridge operates at ten fixed frequencies from 30 to 10^6 rad/sec."

621.317.733:621.317.4:538.221 530

Investigation of an Alternating-Current Bridge for the Measurement of Core Losses in Ferromagnetic Materials at High Flux Densities—I. L. Cooter and W. P. Harris. (*J. Res. Nat. Bur. Stand.*, vol. 57, pp. 103–112; August, 1956.) Accurate values can be obtained at high flux densities if a correction term is included derived from the harmonic components of the exciting current.

621.317.755 531

Equipment for the Continuous Vectorial Display of Alternating Voltages in the Frequency Range 5 kc/s to 3 mc/s—E. C. Pyatt. (*J. Brit. IRE*, vol. 16, pp. 563–567; October, 1956.) A modified form of the equipment described previously (1826 of 1956).

621.317.755 532

Polar-Coordinate Oscilloscopes—G. F. Craven. (*Electronic Eng.*, vol. 28, pp. 422–425; October, 1956.) A circular-timebase circuit with radial modulation is described, using a three-phase Magslip generator.

621.317.755 533

VIAC—a Variable-Interval Automation Controller—M. L. Klein, H. C. Morgan, and J. R. Wood. (*Electronic Eng.*, vol. 28, pp. 425–429; October, 1956.) Designed for use in high-speed oscillograph recording, the unit described permits the actual running time of the recording system to be restricted to periods of particular interest, so as to conserve paper without loss of important information.

621.317.761 534

A Precision Frequency Meter Produced by the Noiseau Measurement Center—J. Boulin. (*Onde Élect.*, vol. 36, pp. 532–540; June, 1956.) Description of receiver-type equipment designed by the Direction des Services Radioélectriques des P.T.T. to cover the frequency range 3–27 mc, using harmonics of 10 kc calibrated by comparison with a 100-kc standard; an accuracy of $10^{-7} \pm 1$ cps is achieved.

621.317.784.029.4 535

An Audio-Frequency Dynamometer Wattmeter—A. H. M. Arnold and J. J. Hill. (*Proc. IEE*, Part C, vol. 103, pp. 325–333; September, 1956.)

621.317.79:537.228.1 536

Apparatus for Investigating the Piezoelectric Properties of Crystals—M. I. Yaroslavski, R. M. Lyutenberg, and V. N. Chernyshov. (*Zh. Tekh. Fiz.*, vol. 26 pp. 439–441; February, 1956.) The operation of the apparatus described is based on the fact that vibrations of a piezoelectric crystal continue for a time after the cessation of an excitation pulse.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

538.566.029.6:61 537

Hazards due to Total Body Irradiation by Radar—H. P. Schwan and K. Li. (Proc. IRE, vol. 44, pp. 1572–1581; November, 1956.) The modes of propagation of em waves in the various tissues of the human body and the resulting development of heat are discussed. At frequencies $\ll$1kmc or $>$3kmc about 40 per cent of incident radiation is absorbed at a body/air interface; over the intervening frequency range the amount absorbed varies between 20 per cent and 100 per cent. Radiation at frequencies $<$1kmc must be guarded against particularly, since, these frequencies produce deep heating and may not be detected by the sensory organs in the skin. It is suggested that an irradiation level of 0.01W/cm² is tolerable.

621-52:061.3 538

Progress in Mechanics under the Combined Influence of Mechanical and Electronic Developments—(*Onde Élect.*, vol. 36, pp. 567–675; July, 1956.) The main part of this issue comprises 13 papers dealing with theoretical, practical, and economic aspects of automation, the use of automatic control apparatus on railways, and specific examples of electronic applications in the testing of fuels and engines, the manufacture of cables, and the classification and retrieval of documents. Several of these papers were presented at a conference held in Paris on November 5, 1955, under the above title.

621.317.79:531.771 539

An Electronic Governor—S. C. Hine. (*Electronic Eng.*, vol. 28, pp. 448–449; October, 1956.) A tachometer-generator driven by the motor to be governed feeds a frequency discriminator whose output controls the power suppled to the motor.

621.317.79:616-1-9 540

A Sensitive Quick—Reacting Cardiotachometer—M. Manzotti. (*Electronic Eng.*, vol. 28, pp. 446–448; October, 1956.)

621.384.6 541

Theory of Strong Focusing [in particle accelerators]—E. L. Burshtein and L. S. Solov'ev. (*C.R. Acad. Sci. U.R.S.S.*, vol. 109, pp. 721–724; August 1, 1956. In Russian.)

621.384.6 542

Experimental Test of the Fixed-Field Alternating-Gradient Principle of Particle Accelerator Design—L. W. Jones, K. M. Terwilliger, and R. O. Haxby. (*Rev. Sci. Instr.*, vol. 27, pp. 651–652; August, 1956.)

621.384.612:538.56.029.6 543

Coherent Radiation from Electrons in the Synchrotron at Centimetre Wavelengths—A. M. Prokhorov. (*Radiotekhnika i Electronika*, vol. 1, pp. 71–78; January, 1956.) An experimental investigation is reported of the radiation from 5-mev electrons traveling in an orbit with a radius of 8 cm. The measured radiated power at 2 and 3 cm λ was about 10^{-6} w, in agreement with calculations. It is suggested that an increase in the radiated power by a factor of 10^6 is possible, and hence powers of 1 w at 1 cm λ, 10^{-2} w at 1 mm λ and 10^{-4} w at 0.1 mm λ should be obtainable.

621.385.833 544

Advance Calculation of Magnetostatic Electron-Optical Imaging Systems—B. V. Borries and F. Lenz. (*Optik, Stuttgart*, vol. 13, pp. 264–276; 1956.) The basic problem in permanent-magnet lenses for electron microscopes is to combine maximum refractivity with minimum external dimensions. Methods are presented for calculating the gap flux from the geometrical arrangement of the magnets and the soft-iron parts. Control of refractivity by displacement of iron parts within the system is discussed.

621.385.833 545

A Model permitting Rigorous Calculation of Electronic Immersion Cylindrical Lense—H. Grümm. (*Optik, Stuttgart*, vol. 13, pp. 277–288; 1956.) The model involves fields which are conveniently investigated by introduction of elliptic coordinates.

621.387:621.398 546

The Dekatron in a Digital Data Transmission System—G. Shand and C. Dean. (*J. Brit IRE*, vol. 16, pp. 533–542; October, 1956.)

621.387.4:519.2 547

On a Probability Problem arising in the Theory of Counters—L. Takács. (*Proc. Camb. Phil. Soc.*, vol. 52, pp. 488–498; July, 1956.)

621.396.91:621.398 548

New Design Aspects of Boomerang Radiosondes for Upper Air Research—H. J. Albrecht. (*Geofis. Pura Appl.*, vol. 33, pp. 121–145; January–April, 1956. In English.) Description of an electronically controlled glider carrying upper-air research equipment. The ascent is by means of normal balloons, and after release the glider is guided in the direction of the base transmitter. The history and details of its aerodynamic and electronic design are given, together with possible applications. The tech-

nique affords safe and prompt return of equipment and simplification of the calibration procedure; a saving of about 60 per cent over normal radio-sonde systems is claimed. 30 references.

621.398:621-52 549

Integral Control with Torque Limitation—J. C. West and M. J. Somerville. (*Proc. IEE*, Part C, vol. 103, pp. 407–419; September, 1956.) "The behavior of a basic remote-position-control system with velocity-feedback stabilization and integral-of-error control is investigated, taking torque limitation of the servo motor into account. It is shown that the transient response deteriorates as the magnitude of the input signal is increased and becomes unstable above a critical value."

621.56:537.311.33:537.322.1 550

Thermoelectric Microrefrigerators—E. K. Iordanishvili and L. S. Stil'bans. (*Zh. Tekh. Fiz.*, vol. 26, pp. 482–483; February, 1956.) A brief preliminary report on experiments with semiconductor elements for refrigeration.

681.81:621.373.431 551

The Univox—A. Douglas. (*Electronic Eng.*, vol. 28, pp. 434–437; October, 1956.) An electronic musical instrument is described using a hard-tube sawtooth generator of high constancy of tuning to produce the tones.

PROPAGATION OF WAVES

621.396.11+[538.566:535.42/.43]+621.396.67 +[621.372.8:538.63 552

Symposium on Electromagnetic Wave Theory—(See 415.)

621.396.11:621.396.65 553

Tropospheric Scatter Propagation—J. A. Saxton. (*Wireless World*, vol. 62, pp. 587–590; December, 1956.) A nonmathematical review is presented of the theoretical background, and practical aspects of point-to-point tropospheric-scatter radio links are discussed.

621.396.11 554

The Present State of Research in the Field of Tropospheric-Scatter Propagation—J. Grosskopf. (*Nachrichtentech. Z.*, vol. 9. pp. 272–279; and 315–329; June/July, 1956.) Summary of results of theoretical and experimental work carried out mainly in the U.S.A.

621.396.11 555

Useful Bandwidth in Scatter Transmission—J. P. Voge. (Proc. IRE, vol. 44, pp. 1621–1622; November, 1956.) Discussion of recent publications on the subject, with reference to previous work by the author (*e.g.*, 510 and 3666 of 1954).

621.396.11.029.45:551.510.535 556

The Polarization of Very Long Radio Waves Reflected from the Ionosphere at Oblique Incidence—W. C. Bain and C. B.-I. Glass. (*Proc. IEE*, Part C, vol. 103, pp. 447–448; September, 1956.) A re-examination of the original evidence [2871 of 1952 (Bain *et al.*)], coupled with a study of additional data, indicates that the mean value of the ratio between the vertical and horizontal electric fields is 5.

621.396.11.029.45:551.510.535:523.75 557

V.L.F. Phase Shifts associated with the Disturbance of February 23rd 1956—J. A. Pierce. (*J. Geophys. Res.*, vol. 61, pp. 475–483; September, 1956.) Observations at Cambridge, Mass., on 16-kc signals from Rugby are discussed. During the disturbance which followed the solar flare at about 0334 U.T., the phase of the received wave was advanced by about 250°. In contrast to the effects observed with sudden ionospheric disturbances in the daytime, which appear to involve phase-shift as well as height variations of the reflecting layer, the night-time observations can be interpreted on the basis of height variations only. The phenomena are discussed in relation to reports of associated observations [*e.g.*, 2716 of 1956 (Ellison and Reid)].

621.396.029.55 558

Rapid Method of M.U.F. Prediction—R. Gea Sacasa. (*Rev. Telecomunicación, Madrid*, vol. 11, pp. 54–59; June, 1956.) Based on the "Spanish Method" (see *e.g.*, 3727 of 1955), nomograms (with captions in Spanish and English) are presented for the rapid assessment of muf and optimum working frequencies for broadcasting, standard-frequency transmissions, amateur, and mobile marine services. The Madrid-New York hour chart is shown with examples to explain its use.

621.396.11.029.55:551.510.535 559

The Intensity of the So-Called Pedersen Ray—K. Rawer. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 797–798; September 10, 1956.) A theoretical calculation indicates that while the geometrical attenuation of the Pedersen ray reflected from the ionosphere is greater than that of the normal ray, absorption in the ionospheric layers is greater for the normal ray. The Pedersen ray may in some circumstances be the stronger of the two.

621.396.11.029.6 560

Field-Strength Calculations for V.H.F. and U.H.F. Transmitters over Level Ground—H. van der Hak. (*PTT-Bedrijf*, vol. 7, pp. 64–68; July, 1956.) Formulas are derived to simplify calculations for the interference and diffraction regions, and numerical examples clarify the use of 13 nomograms included as loose sheets with the journal.

621.396.11.029.62 561

Some Aircraft Measurements of Beyond-the-Horizon Propagation Phenomena at 91.3 Mc/s—B. J. Starkey. (*Proc. IEE*, Part B, vol. 103, pp. 761–763; November, 1956.) "Field-strength measurements at distances extending far beyond the horizon from a transmitter on a frequency of 91.3 mc have been carried out in an aircraft flying at a height of 10,000 ft. The analysis of the results obtained and their correlation with meteorological data suggest that many phenomena of long-distance propagation could possibly be explained by the simple hypothesis of specular reflection from temperature-inversion layers at the tropopause."

RECEPTION

621.396.621:621.396.822 562

Interference Stability of a Filter Autocorrelator Receiver for Pulse Signals—V. I. Chaikovski. (*Radiotekhnika, Moscow*, vol. 11, pp. 24–30; April, 1956.) The output signal/noise ratio is calculated for fluctuation-type interference in the input of a correlation-type receiver using a low-pass filter in the averaging circuit.

621.396.621.029.55:621.314.7 563

Transistor Superregenerative Circuits—D. F. Page. (*Wireless World*, vol. 62, pp. 606–609; December, 1956.) Two receivers suitable for operation at frequencies of 15–25 mc are described. A surface-barrier-transistor oscillator is used 1) in a self-quenching circuit or 2) in a linear circuit in conjunction with a separate transistor quenching oscillator. Circuit diagrams and a table of typical component values are given.

621.396.621.54 564

A General-Purpose Communication Receiver—J. B. Rudd and J. B. Stacy. (Proc. IRE, *Aust.*, vol. 17 pp. 207–217; June, 1956.) Description of a 14-tube superheterodyne receiver designed to meet the specification embodied in the U.K. Merchant Shipping (Radio) Rules, 1952. The rf ranges are 12–60 kc and 100 kc–30mc, and the bandwidth is adjustable between 500 cps and 8 kc in four steps. The turret wave-change unit includes a special mechanism giving a smooth change with positive and precise locking. Additional facilities such as crystal tuning control can be incorporated.

621.396.621.54 565

A Sideband-Mixing Superheterodyne Receiver—M. Cohn and W. C. King. (Proc. IRE, vol. 44, pp. 1595–1599; November, 1956.) "Microwave receivers having bandwidths as much as 22 times greater than the intermediate-frequency amplifier bandwidth have been constructed by generating sidebands on a local oscillator signal and utilizing these sidebands as virtual local oscillators. Both a microwave and a vhf local oscillator signal are injected on a crystal to generate an infinite set of sideband signals separated by the frequency of the vhf oscillator and centered about the microwave oscillator. The low-level received signal mixes with one of these generated virtual local oscillator signals to produce the desired IF signal. The two mixing operations can take place in one crystal or two separate crystals. Measurements have been made of tangential sensitivity and conversion loss and indicate that sensitivities greater than −70 dbm and a continuous bandwidth of 700 mc can be achieved with an intermediate-frequency amplifier having 50 mc bandwidth."

621.396.621.54:621.317.4 566

Transistorized Receiver for Vehicular Radio—S. Schwartz. (*Electronics*, vol. 29, pp. 217–219; October, 1956.) Description of a multiple-superheterodyne military communications receiver with transistors from the IF stage onwards.

621.396.8:621.376.3 567

F.M. Multi-path Distortion—M. G. Scroggie. (*Wireless World*, vol. 62, pp. 578–582; December, 1956.) With a path difference of several miles between two signal components, the comparatively small frequency changes due to fm are sufficient to cause maximum signal fluctuations. These lead to distortions, of magnitude depending on the proportion of the AM which the limiter fails to remove and on the ratio of the signal components. Experiments carried out by the B.B.C. show that as little as 5 per cent signal delayed by 10 miles can cause unpleasant distortion in a typical receiver. The effect of undesired ph.m. is small in the case considered. Remedies suggested are 1) improved amplitude limiting and 2) the use of a direction antenna.

621.396.8.029.62 568

Polarization Discrimination in V.H.F. Reception—J. A. Saxton and B. N. Harden. (*Proc. IEE*, Part B, vol. 103, pp. 757–760; November, 1956.) "An account is given of measurements in the band 40–200 mc of the discrimination likely to be achievable between common-frequency transmissions by the use of orthogonal polarizations. It is shown that the discrimination is determined primarily by the topographical nature of the receiving site, that it is substantially independent of distance from the transmitter and of frequency in the band under consideration, and that the median value is about 18 db. The perturbing effects of pick-up on the feeder and of receiving antenna misalignment are discussed.

621.396.822:551.594.6 569

An Investigation of Atmospheric Radio Noise at Very Low Frequencies—Horner and Harwood. (See 445.)

621.396.822:621.376.23 570

An Experimental Study of Intensity Spectra after Half-Wave Rectification of Signals in Noise—G. E. Fellows and D. Middleton. (*Proc. IEE*, Part C, vol. 103, pp. 243–248; September, 1956.) "Measurement has been made of the spectral intensity of the harmonic

zones which exist at the output of a nonlinear device fed by narrow-band noise and an unmodulated carrier. The spectral shape, the maximum spectral intensity, and the carrier component in each of the first six harmonic zones ($l=0 \cdots 5$) have been determined both theoretically and experimentally for a half-wave ν *th*-law rectifier with $\nu=\frac{1}{2}$, 1 and 2, for a wide range of input carrier/noise ratios. The measuring equipment is discussed in the paper, the theoretical and experimental results are compared, and a number of computed results of practical interest are presented."

STATIONS AND COMMUNICATION SYSTEMS

621.376.56:621.396.5 571

Transmitting System uses Delta Modulation—R. B. Watson and O. K. Hudson. (*Electronics*, vol. 29, pp. 164–166; October, 1956.) A system suitable for voice communication uses a transmitter in which positive or negative pulses from a generator are applied via one of two gates respectively to a local detector; the stepped output from the detector is compared with the modulating signal, the difference voltage controlling the opening of the gates. A pulse repetition rate of 10^5/s is adequate. The remote receiver incorporates a detector similar to that in the transmitter.

621.396.3.029.55 572

Investigation of an Eight-Channel Telegraphy System with Automatic Error Correction—M. Corsepius, H. Logemann, and K. Vogt. (*Nachrichtentech. Z.*, vol. 9, pp. 306–309; July, 1956.) By combining two sets of T.O.M. (Teletype-on-Multiplex) equipment [see also 2533 of 1956 (Corsepius and Vogt)] working on Fl-Duoplex, an eight-channel system with automatic error correction is obtained. Results of tests in both directions over two s.w. radio links are satisfactory.

621.396.41:621.376.3:621.3.018.78 573

Distortion in Frequency-Modulation Systems due to Small Sinusoidal Variations of Transmission Characteristics—R. G. Medhurst and G. F. Small. (Proc. IRE, vol. 44, pp. 1608–1612; November, 1956.) Curves are plotted relating intermodulation distortion in a 600-channel frequency-division transmission system to the amplitude, periodicity, and location of a small sinusoidal variation of either the group-delay or the amplitude characteristic of the system.

621 396.41:621.396.822 574

Method to Calculate Intermodulation Noise—A. P. Bolle. (*PTT-Bedrijf*, vol. 7, pp. 51–57; July, 1956. In English.) This method is applicable to multichannel frequency-division am telephony systems and to fm systems based on them. The noise at zero relative level is determined by complex integration using the characteristic functions of the energy spectra.

621.396.5 575

Single-Sideband Communication Equipment—J. L. Delvaux and M. Byk. (*Onde Élect.*, vol. 36, pp. 520–531; June, 1956.) Equipment manufactured in France is described. A limit of 50 cps is set for the permissible frequency deviation, corresponding to a stability of $10^{-8}-5\times10^{-8}$ at 5–10 mc; afc is dispensed with. For distances up to 1000 km a transmitter power of 10 w is sufficient; a 50-w transmitter gives a range of 2000 km.

621.396.65:621.396.11 576

Tropospheric Scatter Propagation—Saxton (See 553.)

SUBSIDIARY APPARATUS

621-526 577

An Approximate Method for Finding the 'Best Linear Servo Mechanism'—H. H. Rosenbrock. (*Proc. IEE*, Part C, vol. 103, pp. 260–266; September, 1956.) An elementary graphical method is described for evaluating Wiener's solution for the servomechanism which minimizes the rms error when the system is following a signal affected by noise (*Extrapolation, Interpolation, and Smoothing of Stationary Time Series*, 1950). The minimum phase corresponding to a given attenuation characteristic is determined as an intermediate result of the method.

621.3.013.78 578

The Magnetic Field Strength in the Corners of Screened Enclosures (Corner Effect)—H. Kaden. (*Arch. elekt. Übertragung*, vol. 10, pp. 275–282; July, 1956.) The screening effect is reduced in the corners when the external magnetic field is perpendicular to the screen. The explanatory theory is developed and the increase of field strength in the corners is found to be inversely proportional to the 4/3rd power of the distance from the corner. Curves show the direction and increase of the field in the corners. This effect is absent when the external field is parallel to the screen

621.314.634 579

The Operation of Selenium Rectifiers at Audio Frequencies—I. G. Nekrashevich. (*Zh. tekh. Fiz.*, vol. 26, pp. 560–567; March, 1956). A detailed report is presented on an experimental investigation. For sinusoidal voltages over a frequency range of 50 cps–20 kc, the average rectified current is practically independent of frequency, provided the working area does not exceed 1 cm.^{2}.

621.319.339 580

Investigations on Self-Excitation in Band-Type [Van de Graaff] Generators—W. Herchenbach and H. Sigel. (*Z. Angew. Phys.*, vol. 8, pp. 355–360; July, 1956.) The suitability of various insulating materials is investigated; a new symmetrical circuit arrangement is described.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5 581

Pay-As-You-See Television—(*Engineering, Lond.*, vol. 182, p. 434; October 5, 1956.) Outline of a system developed in the U.S.A., in which six groups of signals are transmitted, viz., the coded picture and sound signals, picture and sound programme-announcing signals, a decoding signal, and a signal controlling the financial transaction. Technique for preventing unauthorized reception is indicated.

621.397.5:535.623 582

The Amplitude of the Chrominance Carrier in the N.T.S.C. System—H. Grosskopf. (*Nachrichtentech. Z.*, vol. 9 pp. 289–292; July, 1956.) Calculations and consideration of the color triangle show that for the transmission of normal television pictures the amplitude of the chrominance carrier is likely to be considerably smaller than that required for a bar pattern of pure colors.

621.397.6 583

Improving the Linearity of Vertical Scanning in Television Equipment—E. Giua. (*Piccole Note Ist. super. Poste e Telecommunicazioni*, vol. 5, pp. 366–373; May/June, 1956.) A simple cathode-follower circuit is described which adds a parabolic component to the linear sawtooth voltage waveform, thus linearizing the current waveform in the deflection coils in magnetic deflection systems. The arrangement can also be used to improve es deflection.

621.397.6 584

Slow-Sweep TV for Closed-Circuit Use—H. E. Ennes. (*Electronics*, vol. 29, pp. 140–143; November, 1956.) A system for transmitting still pictures uses a line scan at mains frequency and a frame frequency of 2 to 7 per sec, in conjunction with a long-persistence-phosphor cr-tube screen. The bandwidth of the picture signal can be accommodated on a program-type telephone line. The camera tube is of vidicon type.

621.397.61.001.4 585

Proof of Performance for TV Broadcasting—J. R. Sexton. (*Electronics*, vol. 29, pp. 150–154; November, 1956.) The system of tests imposed by the U.S. FCC before issuing or renewing television broadcasting licenses is described.

621.397.611.2 586

Ebicon Sees in Dark—(*Electronics*, vol. 29, pp. 206–210; November, 1956.) Brief description of a camera tube with a Cs-Sb photocathode and a semiconductor target within which avalanche effects are produced by the passage of the high-velocity photoelectrons. The tube may be associated with an image intensifier.

621.397.62:535.623 587

Three-Phase Detector for Colour-Television Receivers—A. A. Goldberg. (*Electronics*, vol. 29, pp. 157–159; October, 1956.)

621.397.62:535.623:621.385.832 588

Flat Tube for Colour TV—(*Wireless World*, vol. 62, pp. 570–572; December, 1956.) Outline of a lecture to the Television Society by Gabor. The three-beam cr tube is in the shape of a flat glass box which is typically about $4\frac{1}{2}$ inches deep and has a 21 inch-diagonal fluorescent screen. The tube is divided into two halves in depth by a metal plate which carries the whole electron-optical system and serves also as a magnetic screen. The electrons start parallel to the plate from three independently modulated cathodes, pass through an es line-deflection system and then through an em collimator which bends the beam around the edge of the plate. The final bending to cause the beam to strike the fluorescent screen, and the frame scan, are achieved by means of a traveling potential wave. No frame-deflection circuit is required. The shadow mask used for color control is about 0.025 inch from and fixed directly to the fluorescent screen. A cut-away view of the tube and a sketch illustrating the principle of operation of the frame-scanning array are given.

621.397.62:621.397.8 589

A Possible Method of Improving the Definition of a Television Picture—V. F. Samoilov and V. M. Rodionov. (*Radiotekhnika, Moscow*, vol. 11, pp. 44–48; April, 1956.) A circuit and method are described for improving the contrast of weak details. The circuit 1) differentiates the signal, 2) delays the signal derivative for a period equal to the duration of one element of the picture, 3) compares the signs of the derivatives of the delayed and direct signals, and 4) in the event that the signs are opposite, increases the amplitude of the signal.

621.397.5 590

Colour Television Standards [Book Review]—D. G. Fink (Ed.). McGraw-Hill, London, 1955, 520 pp., 64s (*Nature, Lond.*, vol. 178, pp. 764–765; October 13, 1956.) A selection of papers and records of the U. S. National Television System Committee; a considerable amount of the material has been published previously (see in particular Proc. IRE, vol. 42; January, 1954). While useful primarily as a reference work for engineers, the book also includes a nontechnical description of the N.T.S.C. system.

TRANSMISSION

621.396.61:621.373.4 591

An Analysis of Pulse-Synchronized Oscillators—Salmet. (See 386.)

621.396.61.029.62 592

An Experimental Assessment of the Linearity of a V.H.F. Transmitter—D. E. Hampton.

(*Proc. IEE*, Part B, vol. 103, pp. 752–756; November, 1956.) "An experimental procedure is described for testing the assumption that a generator behaves as a linear source. The source admittance is obtained from measurements made when the generator is operating normally, and the problem considered is that of matching this source admittance to the characteristic admittance of the feeder connecting it to a wide-band antenna."

TUBES AND THERMIONICS

621.314.632 593

Note on Turnover in Germanium Contacts—P. T. Landsberg. (*Proc. Phys. Soc.*, vol. 69, pp. 763–765; July 1, 1956.) Discussion of the I/V characteristics of Ge diodes; Burgess's arguments (994 of 1956) are examined and some alternatives are advanced.

621.314.634 594

An Electron-Diffraction Investigation of the Layer Adjacent to a Cadmium Electrode in a Selenium Rectifier—V. A. Dorin and D. N. Nasledov. (*Zh. Tekh. Fiz*)., vol. 26, pp. 284–292; February, 1956.)

621.314.7 595

Internal Oscillations in Transistors—D. Geist. (*Z. Angew. Phys.*, vol. 8, pp. 337–339; July, 1956.) Internally excited oscillations observed in point-contact transistors [see *e.g.*, 2540 and 3392 of 1954 (Hollmann)] and in hook transistors [878 of 1953 (Ebers)] cannot be explained on the basis of stability theory; further experiments are required to clarify the phenomenon.

621.314.7 596

Transit-Time Transistor—G. Weinreich. (*J. Appl. Phys.*, vol. 27, pp. 1025–1027; September, 1956.) Analysis based on that developed by Mason (374 of 1955) is used to show that an appropriately designed transistor can be operated as a three-terminal amplifier in special frequency bands far above α cutoff. These bands lie one on each side of that corresponding to the negative-resistance condition observed when the device is operated as a diffusion-delay diode [3388 of 1954 (Shockley)]. The existence of the bands is generally independent of the magnitude of the base resistance, but their width decreases with increasing base resistance.

621.314.7 597

A Note on the Extended Theory of the Junction Transistor—T. Misawa. (*J. Phys. Soc. Japan*, vol. 11, pp. 728–739; July, 1956.) The examination of dc or lf performance at high injection levels may be based on boundary conditions in terms of either es potential or quasi-Fermi levels. At higher frequencies the latter approach is preferable. The author's approach is contrasted with that of Rittner (3390 of 1954).

621.314.7:546.289 598

Current Gain in Formed Point-Contact *n*-Type Germanium Transistors—D. Haneman. (*Proc. Phys. Soc.*, vol. 69, pp. 712–720; July 1, 1956.) "Experiments on Ge point contact transistors in which collector points of pure donor and acceptor elements are formed show that in general donors appear to be essential to obtain current gain improvements. Successful forming was also achieved with pure gold points. It is assumed that the atoms of the material of the collector diffuse into the germanium during forming. This leads to a change in the amount of lowering of the surface barrier due to the holes injected at the emitter, and accounts for the increased current gain."

621.314.7:546.289 599

Operation of a Crystal Amplifier under Conditions of Carrier Extractions—V. I. Stafeev, V. M. Tuchkevich, and N. S. Yakovchuk. (*Zh. Tekh. Fiz*)., vol. 26, pp. 15–21; January, 1956.) Experiments were conducted with *p-n-p* Ge transistors, based on the extraction of minority carriers as proposed by Angello and Ebert (758 of 1955). The stability of such transistors is good at high temperature; the power amplification is not greatly dependent on temperature and is higher than in amplifiers based on the injection of minority carriers. It is suggested that the principle of extraction can be used in the case of semiconductors with a small energy gap and a high concentration of minority carriers even at room temperature. A combination of extraction and injection enables the dissipated power to be maintained constant, for a given signal level, within a wide range of temperatures.

621.314.7:546.289 600

Relation between Surface and Volume Recombinations in Germanium Triodes with Alloyed *n-p*-Junctions—A. O. Rzhanov. (*Zh. Tekh. Fiz.*, vol. 26, pp. 239–240; January, 1956.) It has been suggested in the literature that the effect of the volume recombination of the excess charge carriers on the characteristics is negligibly small in comparison with that of the surface recombination. Experiments confirming this are briefly described.

621.314.7.001.4(083.74) 601

IRE Standards on Solid-State Devices: Methods of Testing Transistors, 1956. (Proc. IRE, vol. 44, pp. 1542–1561; November, 1956.) Standard 56 IRE 28. S2.

621.383.2 602

Photocells and Photomultipliers with Magnesium Photocathodes for detecting Ultraviolet Radiation—O. P. Dorf, N. G. Kokina, T. M. Lifshits, and D. A. Shklover. (*Radiotekhnika i Elecktronika*, vol. 1, pp. 106–113; January, 1956.) An experimental investigation is reported. The absolute sensitivity and spectral characteristic are not materially affected by the presence of amounts up to a few parts per thousand of Al, Ca, Mn, Zn, Cu, Ni, and Fe. The sensitivity is of the order of 0.32–0.38 $\mu A/\mu w$ at a wavelength of 253.7 mμ; the photomultiplier can detect amounts of power down to 10^{-15} w.

621.383.2 603

Antimony-Lithium Photocathode.—Yu. A. Nemilov and V. E. Privalova. (*Zh. Tekh. Fiz.*, vol. 26, pp. 61–63; January, 1956.) Antimony-lithium photocathodes were prepared having a basic sensitivity of 35–40 μA/lm for a light-source temperature of 2850°. The spectral sensitivity characteristic indicates that the red boundary of the photoeffect is near 6200 Å. The average value of the thermoelectric work function is 1.5 ± 0.1 ev. The average value of the activation energy is 1.0 ± 0.1 ev. The maximum value of the secondary emission coefficient is 15. Heating of the cathode to 100° C decreases the photosensitivity by 50 per cent and increases the work function to 2 ev. The photoconduction processes exhibit appreciable time lag.

621.383.2 604

Investigation of the Phenomenon of Fatigue in Silver-Oxide-Caesium Photocathodes—P. G. Borzyak, V. F. Bibik, and G. S. Kramarenko. (*Radiotekhnika i Elektronika*, vol. 1, pp. 358–369; March, 1956.) Results of an experimental investigation indicate that the fatigue is due not only to changes in the adsorbed film on the cathode and changes in the work function but also to volume processes in the Cs_2O which take place under the influence of the illumination.

621.383.2 605

The Efficiency of Antimony-Caesium Film-Type Photocathodes—P. G. Borzyak, B. I. Dyatlovitskaya, and T. N. Chernysheva. (*Radiotekhnika i Elektronika*, vol. 1, pp. 370–376; March, 1956.)

621.383.4 606

The Photo-effect in Lead Sulphide and Related Materials: Part 2—R. Stein and B. Reuter. (*Z. Naturf.*, vol. 10a, pp. 894–896; November, 1955.) Theoretical interpretation of the observed effects described previously (3249 of 1956).

621.383.42 607

The Influence on the Properties of Selenium Photocells of Near-Infrared Radiation at Low Temperatures—G. Blet. (*C.R. Acad. Sci., Paris*, vol. 243, pp. 798–800; September 10, 1956.) An account is given of resensitization effects observed when Se photocells whose sensitivity has been reduced by cooling are subjected to infrared radiation of appropriate wavelength.

621.383.5 608

High Time Constants in Se Photocells—G. Blet. (*J. Phys. Radium*, vol. 17, pp. 430–439; May, 1956.) Observations have been made of various phenomena with time constants >1 min, including fatigue effects following strong and weak illumination. A qualitative explanation of the observations is provided by a theory based on the density of free electrons and holes in the barrier layer.

621.385:537.2 609

Potential Distribution between Parallel Planes in Electron Tubes—P. L. Copeland, L. M. Sachs and E. C. Czech. (*J. Appl. Phys.*, vol. 27, pp. 816–819; July, 1956.) Formulas and graphs are presented for calculating potential distributions due to space charge between parallel plane electrodes whose dimensions are large compared with their separation.

621.385:537.533:621.375.2 610

Instability in Hollow and Strip Electron Beams—C. C. Cutler. (*J. Appl. Phys.*, vol. 27, pp. 1028–1029; September, 1956.) Observations have been made of the breaking up of beams in magnetic fields; the disturbance can be initiated and controlled by applying a space-periodic deflecting voltage. Use of the effect to produce dc amplification is discussed.

621.385:537.533.087.5 611

A Photographic Method of Studying the Spread of Trochoidal Electron Beams—N. Strandell. (*Kungl. Tek. Högsk. Handl., Stockholm*, no. 106, 13 pp.; 1956.) The vertical and lateral spread of the beam in the trochotron is studied by a photographic method which is applicable at pressures as low as 10^{-5} mm Hg.

621.385:537.533.8 612

Influence of Secondary Electron Emission of Insulators on the Stability of the Parameters of Electronic Valves—N. V. Cherepnin. (*Radiotekhnika i Elektronika*, vol. 1, pp. 38–50; January, 1956.) Experimental results are presented for several types of tube. Steps recommended for effecting improvement include the use of the shortest possible oxide coating on the cathode, increasing the surface resistance, and screening of the supports, use of several types of getters and decreasing the operating voltages.

621.385:621.317.39.082 613

Calculation of Fundamental Parameters for Electronic Valves used for the Measurement of Acceleration—L. A. Goncharski. (*Radiotekhnika, Moscow*, vol. 11, pp. 49–58; April, 1956.) See also 2076 of 1955.

621.385.029.6 614

The Relativistic Magnetron and the Effective Mass Anisotropy—L. Gold. (*J. Electronics*, vol. 2, pp. 17–32; July, 1956.) Development of the analysis presented previously (3203 and 3401 of 1954). Effective mass anisotropy arises

as a consequence of the relativistic condition, the magnitude of the anisotropy being governed by the direction and magnitude of the particle injection velocity and the ratio of the electric and magnetic fields. The cutoff relation for the cylindrical magnetron is deduced.

621.385.029.6 615

Some Properties of Magnetrons Using Spatial-Harmonic Operation—R. G. Robertshaw and W. E. Willshaw. (*Proc. IEE*, Part C, vol. 103, pp. 297–306; September, 1956.) The design of multicircuit magnetrons for low-power operation at frequencies of the order of 10 kmc with voltages <1kv is difficult because of the close tolerances imposed. A design having advantages from this point of view uses an anode with only a few gaps, *e.g.*, two or four, the electron stream interacting with the Fourier space harmonics of the traveling field. A useful tuning range is achieved by adjustment of an external cavity. Some performance details are given for experimental tubes.

621.385.029.6 616

On the Possibility of Extending the Concepts of Similarity to Multiresonator Magnetrons with Different Numbers of Resonators—I. E. Rogovin. (*Radiotekhnika i Elektronika*, vol. 1, pp. 51–70; January, 1956.)

621.385.029.6 617

Oscillations of the Space-Charge Cloud in a Cylindrical Magnetron—V. P. Tychinski and Yu. T. Derkach. (*Radiotekhnika i Elektronika*, vol. 1, pp. 233–244, 344–357; February and March, 1956.) Report of a theoretical and experimental investigation. The conclusions drawn from an approximate calculation of the natural oscillation frequencies of the electron cloud in the magnetron, based on consideration of a small perturbation of the static state, are: 1) the oscillation frequencies are principally determined by the characteristics of the interaction space and are approximately subject to the Hartree threshold-voltage formula, and 2) the dispersion of waves in the electron stream leads to limiting of the excited spectrum and deviation from Hartree's formula. The experimental results confirm the theoretical conclusions.

621.385.029.6 618

Periodic Focusing of Beams from Partially Shielded Cathodes—K. J. Harker. (IRE TRANS, vol. ED-2, pp. 13–19; October, 1955, Abstract, PROC. IRE, vol. 44, p. 274; February, 1956.) Analysis covering both shallow and deep beam scalloping is presented. The relation between the magnetic-field coefficient and the space-charge coefficient is shown in graphs.

621.385.029.6 619

Space-Charge Waves in Velocity-Modulated Electron Beams—P. V. Bliokh and Ya. B. Fainberg. (*Zh. Tekh. Fiz.*, vol. 26, pp. 530–535; March, 1956.) Analysis shows that, for a definite law of velocity modulation, waves with exponentially increasing amplitude can be generated. By taking into account, in the hydrodynamic approximation, the thermal motion of electrons it is possible to determine the frequency dependence of the amplification factor and also the upper frequency limit of amplification.

621.385.029.6 620

An 8-mm Klystron Power Oscillator—R. L. Bell and M. Hillier. (PROC. IRE, vol. 44, pp. 1155–1159; September, 1956.) A floating-drift-tube single-cavity klystron suitable for use in a low-noise cw radar transmitter is described. The beam current is 0.1 A and the beam voltage 3.5 kv; the output power is 12 w. Aluminosilicate glass was used in the construction, to permit baking out at 700° C. A high-convergence electron-optical system permits use of a sprayed-oxide cathode with 1000-h life.

621.385.029.6 621

A Five-Cavity X-Band Klystron Amplifier—G. O. Chalk, B. W. Manley, and V. J. Norris. (*J. Electronics*, vol. 2, pp. 50–64; July, 1956.) Design details and performance figures are presented for a klystron giving an output of several watts with a gain of 70 db. The gain per stage can be predicted with fair accuracy, and the over-all performance can be determined by considering each stage as independent.

621.385.029.6 622

Generation of Electromagnetic Oscillations by a Travelling-Wave Valve with an External Sectionalized Helix—V. S. Mikhalevski and D. N. Venerovski. (*Zh. Tekh. Fiz.*, vol. 26, pp. 526–529; March, 1956.) Experiments indicate that by dividing the helix into a number of sections with suitably chosen parameters it is possible to ensure the generation of an oscillation whose frequency remains constant when the anode voltage and the intensity of the magnetic field vary within fairly wide limits.

621.385.029.6 623

Experimental Investigation of Noise Reduction in Travelling-Wave Tubes—N. B. Agdur. (*Chalmers tek. Högsk. Handl.*, No. 139, pp. 12; 1954.) The noise power output of the tube is studied as a function of the distance between the anode and the helix input. This measurement gives a determination of the length of the space-charge waves in the drift region, the ratio between the minimum and maximum noise factors, and the distance from the anode to the first noise minimum.

621.385.029.6 624

The Nature of Power Saturation in Traveling-Wave Tubes—C. C. Cutler. (*Bell Syst. Tech. J.*, vol. 35, pp. 841–876; July, 1956.) Report of experiments made using a large-scale model of a traveling-wave tube with a helix 10 ft long and 1½ in. in diameter, operated at a frequency of 100 mc with a beam voltage of 400 v. Measurements were made of the efficiency and power output, and of the spent beam velocity and current as a function of rf phase and amplitude. The best value of efficiency, about 38 per cent, is obtained with a value 0.14 for the gain parameter C.

621.385.029.6 625

Nonlinear Wave Propagation in Traveling-Wave Amplifiers—A. Kiel and P. Parzen. (IRE TRANS., vol. ED-2, pp. 26–34; October, 1955.) "A method is given for computing the efficiency of traveling-wave amplifiers with high gain and low C, including the effects of space charge and attenuation. The ballistics of the electrons is governed by the Boltzmann transport equation which, together with the circuit equation, is solved in a power series expansion of the input voltage. Only the first two terms of this series are computed and various nonlinear results are given in the form of curves. It appears that for small C and small convergence parameters overtaking affects the nonlinear operation slightly."

621.385.029.6 626

Recent Developments in O-Type Carcinotron Tubes—P. Palluel. (*Ann. Radioélect.*, vol. 11, pp. 145–164; April, 1956.) See 1904 of 1956 (Palluel and Goldberger).

621.385.029.6:537.533 627

The Electronic Theory of Tape-Helix Traveling-Wave Structures—M. Scotto and P. Parzen. (IRE TRANS., vol. ED-2, pp. 19–25; October, 1955. Abstract, PROC. IRE, vol. 44 p. 274; February, 1956.)

621.385.029.6:[621.372.2+621.372.8 628

Electron Waves in Retarding Systems—Vainshtein (See 338.)

621.385.029.6:621.372.2 629

Investigation of an Interdigital Delay Line—F. Paschke. (*Arch. elekt. Übertragung*, vol. 1 pp. 195–206; May, 1956.) The investigation is directed mainly to the possibilities of obtaining a wide tuning range in backward-wave tubes. Analysis is presented for the all-pass line; the first backward-wave harmonic can be largely suppressed by suitable design. Modification of the all-pass line to give a band-pass characteristic is discussed. An oscillator with an f.m. characteristic similar to that of a reflex klystron can be produced. Highpower wide-band amplifiers can also be designed.

621.385.029.6:621.372.2 630

The Dimensions of Helices in Travelling-Wave Valves—W. Klein. (*Arch. Elekt. Übertragung*, vol. 10, pp. 261–265; June, 1956.) The importance is examined of the proportions and accuracy of the helices where high-power amplification is to be achieved over a given frequency range without risk of self-excitation and undesired fm. Curves show the relation between tube characteristics and helix parameters. See also 1823 of 1955 (Klein and Friz).

621.385.029.6:621.372.413 631

A Method of tuning Resonant Cavities—W. M. Haywood. (*Electronic Eng.*, vol. 28, pp. 395–397; September, 1956.) Tuning arrangements for cavities associated with klystrons are discussed. The effect of enclosing an inductive tuning rod in a fixed glass dome projecting into the cavity, instead of in a bellows, is investigated. The main disadvantage with the glass used was a reduction in cavity shunt impedance of 5–20 per cent; this could be materially reduced by the use of glass with low dielectric loss. The method would not be suitable at high dc power levels, and mechanical difficulties might prevent its use for $\lambda < 3$ cm.

621.385.029.6:621.372.413
:621.376.32[:621.318.134 632

Magnetic Tuning of Resonant Cavities and Wide-Band Frequency Modulation of Klystrons—G. R. Jones, J. C. Cacheris, and C. A. Morrison. (PROC. IRE, vol. 44, pp. 1421–1438; October, 1956.) A detailed account of work previously reported briefly [3441 of 1955 (Cacheris *et al.*)]. Theoretical and experimental results are presented. Linear frequency deviations up to 240 mc are obtained with only 13 per cent amplitude variation.

621.385.029.6:621.385.2:621.396.822 633

Monte Carlo Calculation of Noise Near the Potential Minimum of a High-Frequency Diode—P. K. Tien and J. Moshman. (*J. Appl. Phys.*, vol. 27, pp. 1067–1078; September, 1956). Details are given of a method suitable for carrying out the calculation with a high-speed electronic computer, starting with the generation of random numbers to simulate the electrons emitted by the cathode. Figures were obtained for a total of 3000 unit time intervals. The reduction of noise current due to space-charge smoothing is estimated. Application of the results to microwave beam tubes leads to a minimum-noise-figure/frequency curve exhibiting a sharp minimum at about 2.5 kmc and a flat maximum at about 4 kmc and an approach to the full shot-noise value of 6.3 db at higher frequencies.

621.385.029.6:621.396.822 634

Klystron Oscillator Noise Theory—R. L. Bell. (*Brit. J. Appl. Phys.*, vol. 7, pp. 262–266; July, 1956.) The principal sources of undesired am and fm in a floating-drift-tube klystron are shot and partition noise in the beam at the oscillation frequency and its harmonics, except at lowest modulation frequencies where flicker noise predominates in the am. Formulas are presented for the background noise temperature generated by the am and for the fm spectral density.

621.385.029.6:621.396.822 635
Spurious Modulation in Q-Band Magnetrons—T. M. Goss and P. A. Lindsay. (PROC. IRE, vol. 44, pp. 1474–1475; October, 1956.) Further evidence is presented confirming the occurrence of the effects reported by Cutler (1256 of 1956).

621.385.029.6:621.396.822:621.372.5 636
The Equivalent Noise Quadripole of Transit-Time Valves—H. Bauer and H. Rothe. (*Arch. Elekt. Übertragung*, vol. 10, pp. 283–298; July, 1956.) Application of previous work (380 above) to various types of transit-time tubes. The network parameters are used to analyze the sources of noise, as illustrated by the example of a defective low-noise traveling-wave tube. Fundamental laws of transit-time tubes applicable to the small-signals case are examined.

621.385.032.21:537.533 637
Field Emission and Field-Emission Cathodes—D. V. Zernov and M. I. Elinson. (*Radiotekhnika i Elektronika*, vol. 1, pp. 5–22; January, 1956.) A review is presented of theoretical and experimental work. 54 references, including 8 to Russian literature.

621.385.032.213 638
The Physical Properties of a Porous Metallic-Film Thermionic Cathode: Part 1—N. D. Morgulis. (*Zh. Tekh. Fiz.*, vol. 26, pp. 536–548; March, 1956.) Various aspects of the operation of a cathode consisting of a w base coated with a Ba monolayer in a state of dynamic equilibrium are considered. Experimental data are given on the formation of Ba in the cathode material, its subsequent diffusion to the surface of the cathode, evaporation from this surface, etc., and on the operation of these cathodes in electronic devices. A brief report is also presented on an electron-diffraction investigation into the structure of the cathode.

621.385.032.213 639
Bariated Tungsten Cathode: Part 1—General Studies—Y. Koike and T. Shibata. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 7, pp. 67–74; September, 1955.) The effect of Si, Zr and WC, used as reducing agents, on the emission of capillary cathodes formed of sintered mixtures of barium silicates and tungsten is described; good results are obtained with Si and Zr.

621.385.032.216 640
Measurement of the Electrical Conductivity of the Oxide-Coated Cathode—T. B. Tomlinson and R. E. J. King. (*Brit. J. Appl. Phys.*, vol. 7, pp. 268–269; July, 1956.) Two similar Ni annuli with the oxide sandwiched between them formed the cathode, which was heated by 1-mc eddy currents. Conductivity and emission were measured at temperatures from 300° to >1000°K.

621.385.032.216 641
Investigation of an Oxide Cathode on a Core of Tungsten-Activated Nickel—Yu. G. Ptushinski. (*Zh. Tekh. Fiz.*, vol. 26, pp. 232–234; January, 1956.) A detailed report on an experimental investigation of the activating mechanism of *W* in oxide cathodes.

621.385.032.216 642
The Evaporation of Barium from 'L' Cathodes—I. Brodie and R. O. Jenkins. (*J. Electronics*, vol. 2, pp. 33–49; July, 1956.) The possibility of reducing the evaporation rate by altering the porosity of the tungsten disk or by varying the Ba compound used to supply the activating Ba has been investigated experimentally. Differing theories regarding the mechanisms of limitation of Ba evaporation are discussed and their range of validity indicated. See also 2918 of 1956.

621.385.032.216 643
Thermionic Emission from Oxide Cathodes as a Function of Core-Metal-Impurities—H. Bender. (*Le Vide*, vol. 11, pp. 112–128; May/June, 1956. In French and English.) A review including tables showing the effect of various core impurities on emission.

621.385.032.216 644
Internally Coated Cathodes—P. O. Hawkins and J. S. Thorp. (*Nature, Lond.*, vol. 178, pp. 380–381; August 18, 1956.) Measurements were made of the emission from hollow cathodes for different values of temperature electric field and magnetic immersion field. The results confirm the view advanced previously [1260 of 1956 (Bright and Thorp)] that the emission occurs mainly at the edges of the hole. Currents much in excess of the space-charge-limited values may be obtained because of the predominance of the edge effect.

621.385.032.216:621.385.029.6 645
The Mechanism of Pulse Temperature Rise on the Surface of Thermionic Cathodes—R. Dehn. (*Brit. J. Appl. Phys.*, vol. 7, pp. 210–214; June, 1956.) Spontaneous fluctuations observed in the cathode surface temperature of pulsed magnetrons are probably caused by resistive heating due to the passage of current through a highly resistive surface layer; the phenomenon probably occurs in other thermionic emitters, particularly of the oxide-coated type and must affect both operation and life.

621.385.032.216:621.396.822 646
Notes on a Source of Intermittent Noise in Oxide-Cathode Receiving Valves—M. R. Child. (*Proc. IEE*, Part B, vol. 103, pp. 667–668; September, 1956.) "One form of 'spike' noise in high-grade tubes is shown to be due to intermittent leakage between electrodes caused by the deposition of barium or magnesium, or both, on the supporting micas. The magnitude of the effect is shown to increase with the anode voltage between 100 and 300 volts. No effect can be detected below 60 volts in the case of passive cores. The effect may be successfully avoided by the use of mica shields."

621.385.032.24 647
Study of the Surface of the Grid in a Vacuum Tube—M. Wada and A. Sato. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 6, pp. 137–156; 1955.) In an experimental investigation of grid emission due to contamination by cathode material, it was found that at the same working temperature a control grid of gold wire is deactivated, presumably by the diffusion of gold atoms through the contaminated layer, while a molybdenum grid is activated. The results are discussed in relation to factors affecting work function.

621.385.3/.5 648
Determination of the Thermal Behaviour of the Control Grid of a Valve from its Emission Current Measured by a Pulse Method—V. Ya. Kunin and M. O. Ratsun. (*Radiotekhnika i Elektronika*, vol. 1, pp. 377–380; March, 1956.) The results obtained in a typical tube by the pulse method described agree with those calculated from an equation given by Wagener (*Z. Tech. Phys.*, vol. 18, pp. 270–280; 1937. Abstract 4112 of 1937.)

621.385.83 649
Some Problems in the Theory of Focusing of Electron Beams—P. P. Kas'yankov. (*C.R. Acad. Sci. U.R.S.S.*, vol. 108, pp. 813–816; June 11, 1956. In Russian.)

621.385.832 650
Limits of Electron-Beam Focusing—U. Pellegrini. (*Piccole Note Ist. super. Poste e Telecommunicazioni*, vol. 5, pp. 346–360; May/June, 1956.) Factors limiting the reduction of the spot size in cr tubes are examined, and a simple equation for the spot radius is derived, taking account of the spherical aberration of the electron lens. A nomogram is given for evaluating the minimum attainable spread due to space-change effects under any beam conditions. The possibility of compensating spherical aberration by means of space-charge effects is mentioned [See also 1363 of 1956 (Dolder and Klemperer)].

621.385.832:621.397.62:535.623 651
Flat Tube for Colour TV—(See 582.)

621.385.832.032.7.002.2 652
The Choice of a Mould for the Manufacture of Glass Cones for Cathode-Ray Tubes with a Rectangular Screen by the Centrifugal Method—V. Ya. Savel'ev. (*Zh. Tekh. Fiz.*, vol. 26, pp. 640–645; March, 1956.) Difficulties arise when the centrifugal method is applied to the manufacture of tubes with a rectangular screen, since the liquid glass tends to concentrate at the edges of the pyramid to which the screen is to be sealed. A calculation is made of the shape of a mould which would ensure that glass would reach all points of the wide part of the tube simultaneously. Some photographs of cones for 21-in. tubes produced in this manner are shown.

621.387 653
Thyratron Behaviour at Low Anode Voltages—(*Mullard Tech. Commun.*, vol. 2, pp. 242–247; July, 1956.) A discussion of effects including delayed onset of anode conduction and delayed attainment of full conduction, resulting from use of anode voltages as low as or lower than twice the grid voltage.

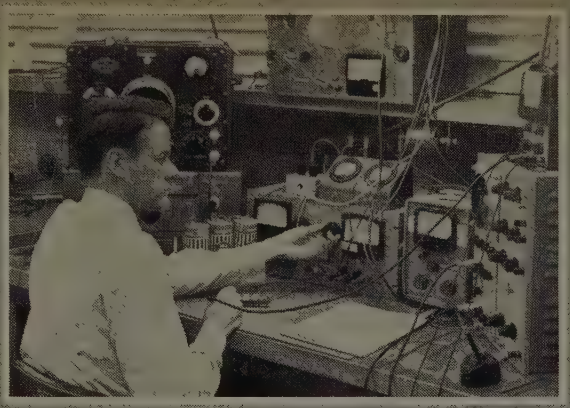
621.387 654
Firing Delay and Build-Up Time of the Discharge in the Thyratron—H. Appel and E. Fünfer. (*Z. Angew. Phys.*, vol. 8, pp. 322–327; July, 1956.) Measurements were made of the relation between the amplitude of the firing pulse and the delay and build-up times. For tetrodes, the delays are of the order of 10^{-7}s; for triodes, of the order of 10^{-8}s; they are nearly independent of grid bias. Over the range investigated, the build-up time varies with the pulse amplitude in triodes, but not in tetrodes.

621.387 655
Confirmation of the Laws developed by Rogowski and Fucks for Firing in Commercial Cold-Cathode Discharge Tubes—W. Kluge and A. Schulz. (*Z. Angew. Phys.*, vol. 8, pp. 328–331; July, 1956.)

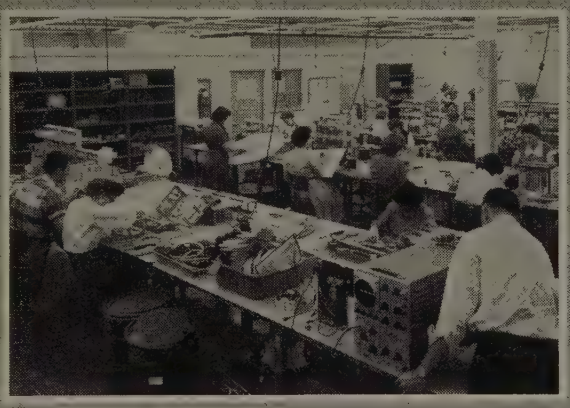
621.387:681.142 656
Gas-Diode Voltage Characteristics—(*Elect. Rev., Lond.*, vol. 158, pp. 1029–1030; June 15, 1956.) An inexpensive method has been developed at the National Bureau of Standards for equalizing and stabilizing the voltage characteristics of low-cost indicator lamps, such as neon tubes, so as to render them suitable for use as computer elements. The process involves the application of pulses simultaneously to a large number of tubes.

MISCELLANEOUS

621.3.002.2 657
Quality Control in Electronics—M N. Torrey (PROC. IRE vol. 44, pp. 1521–1530; November, 1956.) A review, with 65 references, discussing the objects and techniques of quality control in the manufacture of electronic equipment.



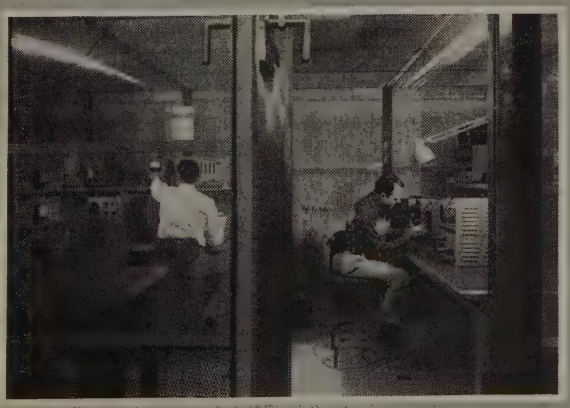
RESEARCH AND DEVELOPMENT



PILOT LINE PRODUCTION



FINAL ASSEMBLY



TESTING IN SCREEN ROOM

COMMUNICATIONS at Ramo-Wooldridge

Communications activities at The Ramo-Wooldridge Corporation include research, development, and manufacture of advanced types of radio communication systems, ground-reference navigation systems, and electronic countermeasure systems. Major programs are in progress in each of these fields.

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In the work currently under way, some systems are in the laboratory development stage, some in the flight test stage, some are in production. Several types of systems developed and manufactured by Ramo-Wooldridge are in extensive operational use.

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- Systems study and analysis
- Airborne transmitters
- Transistorized video and pulse circuitry
- Airborne receivers
- Reconnaisance systems
- Digital communications systems

The Ramo-Wooldridge Corporation

5730 ARBOR VITAE STREET • LOS ANGELES 45, CALIFORNIA



Whom and What to See at the Radio Engineering Show

(Continued from page 170A)

Chicago Standard Transformer Corp.
3501 West Addison St.
Chicago 18, Ill.
Booth 1203

P. N. Cook, R. I. Reigel, O. Williams, V. Racanelli



*Line of magnetic Amplifiers in stock ready for immediate shipment.

Christie Electric Corp.
3410 West 67th St.
Los Angeles 43, Calif.
Booth 2810

E. E. Hughes, R. L. McDonald, C. F. Paddock, E. A. Janse, Martin Silver, Leonard Blakely

*High Capacity *SILICON* automatically Regulated DC Power Supplies up to 1000 Amperes continuous capacity. DC voltage ranges 6 to 40 volts. DC Regulation to 5%. Response Time 0.1 second. Ripple 1% R.M.S.

Cinch Mfg. Corp.
1026 S. Homan Ave.
Chicago 24, Ill.
Booths 2535-2536

▲S. Del Camp, H. Z. Benton, ▲J. R. Hunt, C. W. Nelson

Tube sockets and shields—micro-connectors—terminal strips—battery plugs & sockets—transistor sockets—strapnuts—tube holders—metal stampings—printed circuit boards—printed circuit sockets and components.

Circle Dot Corp., Booth 4016
Shalvoy's Lane
Danbury, Conn.

J. J. Root, J. L. Thompson, J. Nidnight, J. Green, G. Dunham, J. Cole, R. Psolmm

Modular system of mechanically marked and prefabricated forms designed to save layout time. Production and tooling costs. Adaptable for cabinets and chassis.

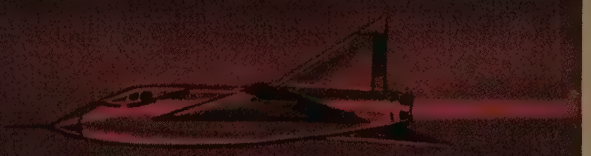
C. P. Clare & Co.
420 Lexington Ave.
New York 17, N. Y.
Booth 2402

James W. Conceagh, Harold W. West, James H. Riley, Thomas J. Connors, Ed Holt, Mr. Frank Wilmot, T. J. Burrojy, Rober Shires

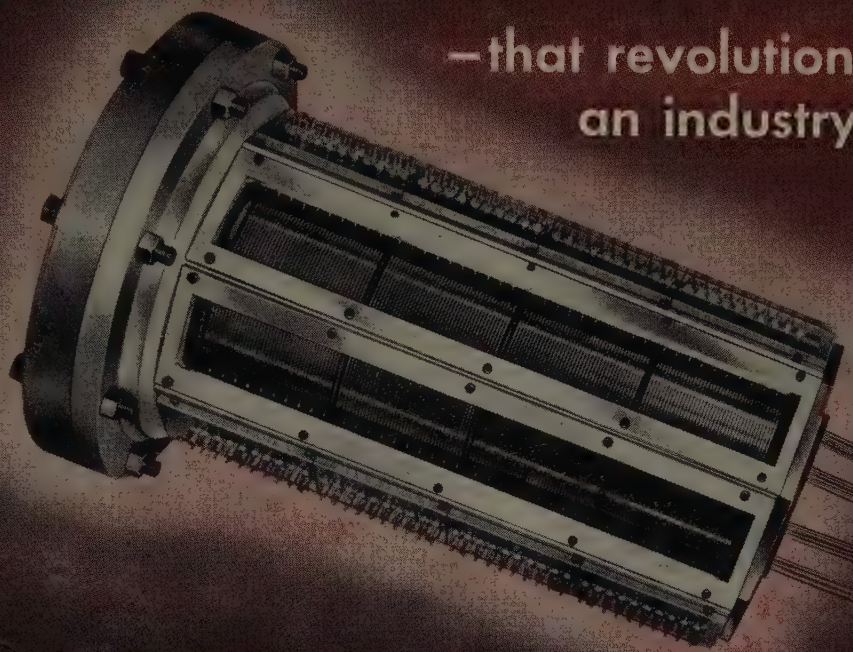
MERCURY WETTED CONTACT RELAYS. Contacts never wear out, never get dirty, never lock or weld, never get out of adjustment—no contact bounce during billions of operations.

(Continued on page 180A)

A DESIGN CONCEPT



—that revolutionized an industry!



ELECTRO TEC

PRECISION MACHINED ONE-PIECE CONSTRUCTION

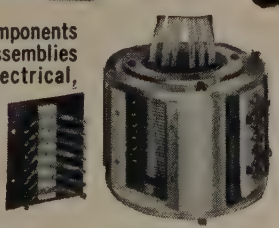
SLIP RING & COMMUTATOR ASSEMBLIES

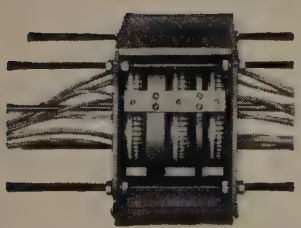


Diameters of multi-ring assemblies from .035" to 36"



Individual components or complete assemblies to precise electrical, mechanical, and environmental specifications.





Uniformly hard rings, low noise, minimum friction and dimensional stability.



An Unmatched Record of Performance

Today, Electro Tec Slip Ring and Commutator Assemblies are the choice of leading aircraft, instrument, and component manufacturers throughout the world. Our units are selected for Gyro and Servo applications, for Telemetering and Radar devices, for Guidance systems, and Automation equipment... where sustained and reliable performance is a requisite.

Facilities Available to Serve You

Plants in South Hackensack, N. J., Blacksburg, Va., and Ormond Beach, Fla., are currently producing a wide variety of Slip Ring, Commutator, and Brush Block Assemblies, Precision Selector Switches, and Miniature Relays. Complete Engineering Facilities and Branch Sales Offices in Los Angeles, Minneapolis, Chicago, and Waltham, Mass. are geared to service your requirements.

Write for fully illustrated literature.



*PATENT No. 2,696,570

See us at the IRE Show! BOOTHS 1216, 1218, 1220

ELECTRO TEC CORP.

SOUTH HACKENSACK, NEW JERSEY

PRODUCTS OF PRECISION CRAFTSMANSHIP

Coaxial Variable Attenuator

Low Insertion Loss!

Broadband



Unique in the Microwave Field!

NOW—for the first time A Broadband Very Low Insertion Loss Attenuator.

INSERTION LOSS:
1 db maximum for 40 db unit.
½ db maximum for 20 db unit.

ACCURACY:
(±) .25 db for 100% frequency range.

AVAILABLE FREQUENCY RANGE:
100-3,300 Megacycles.

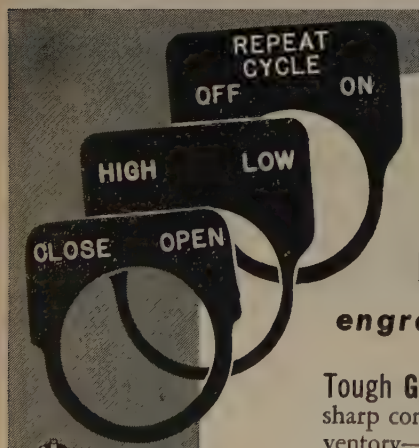
AVAILABLE TYPES:
Type N—(3/8″) or (7/8″) line. Essentially Linear Scale 7″ long.

Write for our Component Catalogue, it is the most complete and comprehensive in the field . . . available on request.



DOUGLAS MICROWAVE CO., Inc.
252 East Third St., Mt. Vernon, N. Y
MOunt Vernon 8-6900

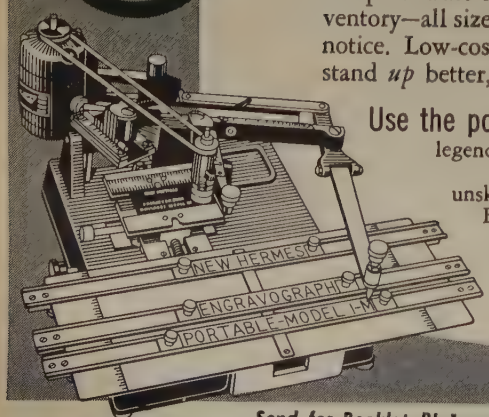
Visit our exhibit, Booth 3712, 3rd floor, IRE Show



Chip-proof PLASTIC LEGEND PLATES

engraved in your own plant

Tough **GRAVOFLEX** blanks are laminated in sharp contrast colors. No need to keep large inventory—all sizes, varied colors available on short notice. Low-cost GRAVOFLEX legend plates stand *up* better, stand *out* better!



Use the portable **ENGRAVOGRAPH** to mark legend plates to your specifications, on the spot, when you need them—with unskilled labor, because it's tracer-guided. Big savings on short runs and "one-shot" jobs. Eliminates costly delays. 17,000 Engravographs in use.

See demonstration at
BOOTH #1234
I. R. E. SHOW

Send for Booklet BL-1 and sample plate.

new hermes **ENGRAVING MACHINE CORP.**
13-19 UNIVERSITY PLACE, NEW YORK 3, N. Y.

Whom and What to See at the Radio Engineering Show

(Continued from page 178A)

Cleveland Container Co.
6201 Barberton Ave.
Cleveland 2, Ohio
Booth 2317

Jay Sebesky, R. S. Pettigrew, ▲ R. A. Murray, ▲ L. F. McFarlane, ▲ Hugh O'Reilly, ▲ Pete Paisley



Nylon "one-piece" Coil forms with collar and terminals attached. *Improved Torkrite Forms, Internally threaded and Embossed—Clevelite Phenolic Tubing of Various Grades and Fabrications.

Coaxial Connector Co., Inc., Booth 3825
37 North 2nd Avenue
Mount Vernon, New York

William R. Clayton, Monroe Keiser, M. Brady

Special & standard coaxial connectors, cable & harness assemblies, radar & aircraft antennas, miniature connectors, microwave components, connector assemblies.

Cohehn, Inc.
Passaic Ave.
Caldwell, N. J.
Booth 4055

George L. Henzel, David F. Cook, William E. Bellars, Harry Welsh.

Automatic High Velocity Spray Equipment and Fractionally Distilled Solvent for the Critical cleaning of Electrical Contacts in Relays, Vibrators, Choppers, Voltage Regulators, and Sensitive Switches.

Sigmund Cohn Corp.
121 S. Columbus Ave.
Mount Vernon, N. Y.
Booths 2428, 2521

Richard Cohn

Base metals; Precious metals, fine wire and ribbon, bare drawn, etched, electroplated, enamel insulated.

(Continued on page 182A)

If you are unable to attend the IRE Convention, or wish to refresh your memory afterwards on the details of any paper presented in the technical sessions, you may order copies of the "Convention Record" from the Institute of Radio Engineers, 1 East 79th St., New York 21, N.Y.

NEW DEVELOPMENTS IN PRINTED CIRCUIT SOCKETS BY CINCH



No. 22920

These latest developments in printed circuit sockets offer the highest quality in material and workmanship to meet the most rigid government specifications. They insure positive contact and hold tubes securely in place. Maintenance and replacement easily made. They provide maximum insulation resistance and minimum high frequency loss. Adapted to printed circuit boards up to and including ⅛" thick.

No. 22920—7 contact miniature molded vertically mounted socket with JAN type shield base. Mica insulation. Silver plated phosphor bronze contacts drop through .062" dia. clearance holes arranged on a .1" X and Y axis.

EXP-9553 — 8 contact button base subminiature molded, vertically mounted socket. Mica insulation. Silver plated beryllium copper contacts drop through .070" dia. clearance holes arranged on a .1" X and Y axis.

EXP-9553A—Same as above except insulation to withstand temperatures above 200° Centigrade.



EXP-9553

No. 22024—7 contact flat press subminiature molded, vertically mounted socket for conventional wiring. Assembled with a special shield base to accept a subminiature shield with the "J" lock. Flat sided retaining nuts and screws are provided for mounting. Mica insulation. Silver plated beryllium copper contacts.



No. 22024

No. 22023—Same as above except insulation to withstand temperatures above 200° Centigrade.

No. 22022 — 8 contact button base subminiature molded vertically mounted socket for conventional wiring. Assembled with special shield base to accept a subminiature shield with the "J" lock. Mica insulation. Silver plated beryllium copper contacts.

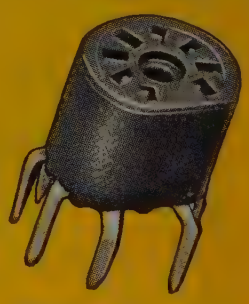


No. 22022

No. 22021—Same as above except insulation to withstand temperatures above 200° Centigrade.

EXP-9542—7 contact miniature molded right angle mounted socket with JAN shield base. Mica insulation. Silver plated beryllium copper contacts drop through .062" dia. clearance holes arranged on a .1" X and Y axis.

Sockets shown enlarged.



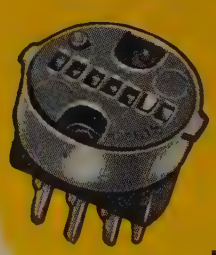
EXP-9553



EXP-9542

EXP-9561 — 7 contact flat press subminiature molded right angle socket. Mica insulation. Silver plated beryllium copper contacts drop through .046" dia. clearance holes arranged on a .1" X and Y axis.

EXP-9561A—Same as above except insulation to withstand temperatures above 200° Centigrade.

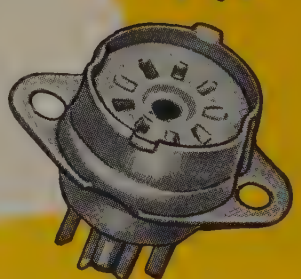


No. 22024



EXP-9561

EXP-9562—8 contact button base subminiature molded, right angle mounted socket. Mica insulation. Silver plated beryllium copper contacts drop through .046" dia. clearance holes arranged on .1" X and Y axis.



No. 22022

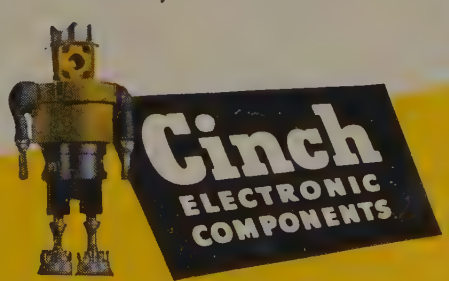


EXP-9562

EXP-9562A — Same as above except insulation to withstand temperatures above 200° Centigrade.

These sockets will take care of the three types of receiving tubes in use today: Miniature, Flat Press and Button.

The contacts are so spaced that they can be mounted in an incremental drill pattern as stated. This fact together with the exact precision and uniformity of Cinch sockets make them ideal for automatic assembly.



Centrally located plants at Chicago, Illinois; Shelbyville, Indiana; LaPuente, California; St. Louis, Missouri.

VISIT CINCH BOOTH No. 2535, AT THE IRE SHOW

For Your Connector Requirements — You Can Depend On Cinch

CINCH MANUFACTURING CORPORATION

1026 South Homan Ave., Chicago 24, Illinois

Subsidiary of United-Carr Fastener Corporation, Cambridge, Mass

MAGNETIC COMPONENTS OF EXCEPTIONAL RELIABILITY

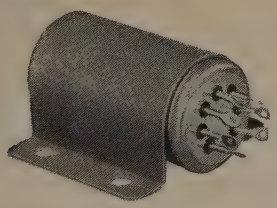
for the discriminating engineer



MAGNETIC AMPLIFIERS for instrumentation and control are unusually stable. Design of mixing, lead, and lag networks to work with these amplifiers is straight-forward. Normal gain of Type M-943 is 2.5 volts ±1 db of output for each 100 microamperes of input. Units draw less than 3 watts from 400 CPS supply, occupy about 6 cu. in.

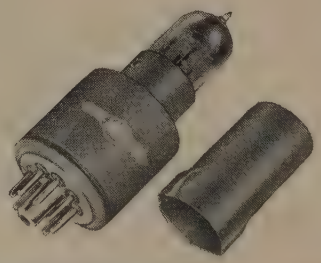
CHOPPERS such as this 60 CPS unit are widely used as modulators because of their inherently stable null. Contacts handle 2 MA up to 100 volts.





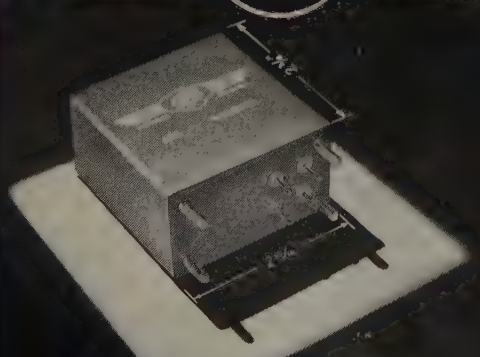
HERMETICALLY SEALED for operation in any atmosphere, this 400 CPS unit draws relatively low drive power, operates up to 125C.

DRIVER for 400 CPS chopper provides 6.3 RMS volts, enables you to obtain all advantages of a 400 CPS chopper in equipment powered from 60 CPS lines.



AIRPAX

DESIGNERS ENGINEERS



VIBRATOR power supplies such as this 400 CPS inverter designed and manufactured to your needs. Our 400 CPS power vibrators keep these units small and light.

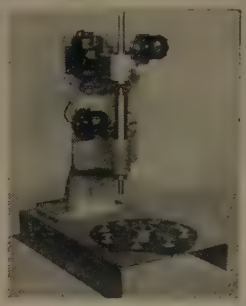
For full details write: Airpax Products Co. Data Service Office, Baltimore 20, Md.

Whom and What to See at the Radio Engineering Show

(Continued from page 180A)

Coil Winding Equipment Co.
19 Maxwell Ave.
Oyster Bay, L. I., N. Y.
Booths 4502, 4601

▲ Howard A. George, ▲ Blanche A. George, ▲ John E. Fogelberg, James H. George, Michelina Minicozzi



Newest developments in winding equipment, including laboratory and high production designs. First showing of equipment for completely automatic production of various types of coils. Engineering help available.

Coleman Engineering Co., Inc., Booth 1624
6040 West Jefferson St.
Los Angeles 16, Calif.

A. J. Edwards, J. Albeck, P. Hubay

A new Coleman decimal "Digitizer" with isolated contact output for direct IBM punch operation; automatic digital positioning system (digits to shaft); digital printout of analog data; data collection & logging systems.

Collins Radio Co.
855 35th St. N.E.
Cedar Rapids, Iowa
Booths 1101-1106

Latest developments in SSB HF communication equipment. Airborne, Amateur & Industrial Equipment.

Color Television, Inc.
Booth 3231
See: California Technical Industries

Comar Electric Co.
3349 West Addison St.
Chicago 18, Ill.
Booth 3821

L. E. Noelck, R. Valleau, L. Chocola.

*Type "TL" Telephone Type Fast Acting, Sensitive, Long Life, Multi-Pole *Relays, including hermetically sealed; switches, coils, solenoids and transformers.

Combined Book Exhibit, Inc., Booth 4121
950 University Ave.
New York 52, N.Y.

Thomas J. McLaughlin, H. A. Simmons, W. Tarbox, D. Carrio, S. Anson, Clarence Girard

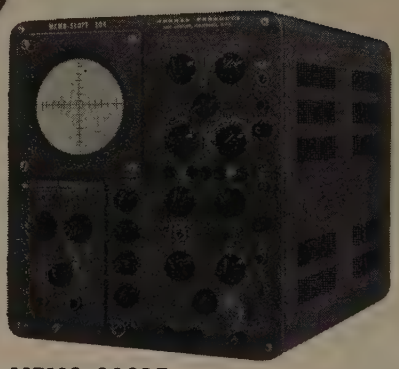
New ideas are recorded in new books. Here they are in the Combined Book Exhibit.

(Continued on page 184A)

* Indicates new product.
▲ Indicates IRE member.

Three unusual direct-display storage tubes by Hughes





MEMOTRON

FEATURES: bright display . . . constant and uniform intensity of presentation . . . no perceptible transient decay . . . simplifies photography. APPLICATIONS: transient analysis . . . spectrum analysis . . . direct comparison of wave forms. SPECIFICATIONS: 100,000 inches/sec. writing speed . . . stores traces until intentionally erased . . . erasure triggered by push-button, or programmed voltage . . . electrostatic focusing and deflection.

MEMO-SCOPE

Model 104, incorporating MEMOTRON, is a new memory oscilloscope with 5 optional preamplifiers to satisfy the most critical production, test and laboratory requirements.



TONOTRON

FEATURES: half-tone presentation . . . excellent grey scale . . . controllable decay rate . . . compact design. APPLICATIONS: closed circuit TV . . . instrumentation . . . P.P.I. . . . narrow band, slow scan TV. SPECIFICATIONS: 1,000 foot-lamberts brightness at 10 kv . . . electrostatic focusing . . . magnetic deflection . . . . 60 lines per inch resolution . . . writing speed of 150,000 inches/sec.



TYPOTRON

FEATURES: high brightness . . . permanent display until intentionally erased . . . rapid display of printed data . . . 63 character matrix. APPLICATIONS: digital computers . . . teletype reception . . . wherever printed data must be displayed rapidly for use by human operator. SPECIFICATIONS: writes up to 25,000 characters/sec. . . . permanent storage until erased . . . almost instantaneous erasure . . . electrostatic focusing and deflection.

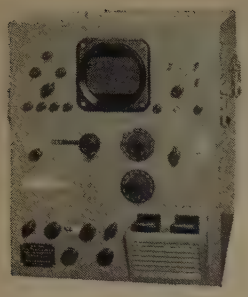
See demonstrations of these tubes and MEMO-SCOPE *at the I.R.E. Show, booths 2801, 2803, 2805, Second Floor. For additional information write to:*

HUGHES PRODUCTS • ELECTRON TUBES
International Airport Station, Los Angeles 45, California

HUGHES PRODUCTS

© 1957, HUGHES AIRCRAFT COMPANY

CO-AXIAL SWITCHES, MICROWAVE TEST EQUIPMENT and PRIMARY POWER STANDARDS



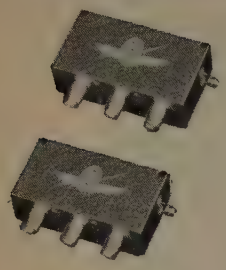
PULSE POWER CALIBRATOR

MODEL PCX-1 PULSE POWER CALIBRATOR is an extremely precise instrument for calibrating pulse power measuring devices in the 925- to 1225-mc frequency range and for measuring power between −10 and +63 dbm to within 0.5 db. It is the first in a series which includes similar calibrators designed for the 3000-mc, 5000-mc and 9000-mc bands.

This equipment employs a new method which permits far greater accuracy (other than calorimetric) than heretofore achieved. It establishes a measurement reference level at the time of each use.

Ease of operation is assured by the notch-and-reference-line display, by the automatic centering of pulses on the display, and by the direct reading of power measurements.

The removable bisectional cover, frame construction, hinged and pivoted subchassis assure easy accessibility for servicing.



MINIATURIZED SWITCHES

A new line of inexpensive, miniature, light-weight, versatile co-axial switches.

GENERAL CHARACTERISTICS

Frequency Range: 0 to 10,750 mc/s. **VSWR:** 1.25 at 3000 mc/s — 1.5 at 10,750 mc/s. **Insertion Loss:** 0.25 db up to 9000 mc/s. **RF Power Rating:** 100 watts average — 1500 watts peak. **Voltage Rating:** 500 volts peak. **Crosstalk:** greater than 70 db up to 9000 mc/s. **Impedance:** 52 ohms nominal. **Actuator Voltage:** 28 volts DC nominal. **Actuator Power:** 10 watts average continuous. **Operative Life:** 100,000 cycles. **Operating Temperature:** −55°C to +85°C. **Connector Type:** N, BNC, or C. **Weight:** 10 ounces. **Dimensions:** 2.5 in. x 2.875 in. x 0.875 in. **Switching Arrangement:** SPDT. **Mounting Features:** Mounts flat against panel, chassis or frame; multiple-stacked compactly.



MANUAL CONTROL SWITCHES

Compact, lightweight — available in Radial; parallel connector configuration.

GENERAL CHARACTERISTICS

Frequency Range: 0 to 10,500 MC. **VSWR:** 1.2:1 max. at 3000 MC. **Insertion Loss:** 0.3 db max. **Crosstalk:** greater than 60 db at 3000 MC, greater than 40 db at 10,500 MC. **Operation Life:** 10,000 cycles, min. **Construction:** weatherproof. **Connectors:** N, BNC, C, HN, BN, LN. **Positions:** 2, 3, 4 and 6: single and double pole. **Easily adaptable for specialized usage.**



REMOTE CONTROL SWITCHES

28 V. DC., 110 V. DC. — Compact, lightweight — available in Radial, spring return; Radial, transfer; parallel connector configuration.

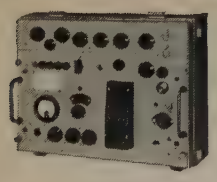
115 V. AC., 60 cycle. — Compact, lightweight — available in Radial, spring return; parallel connector configuration.

GENERAL CHARACTERISTICS — See Above



"S" BAND BEACON

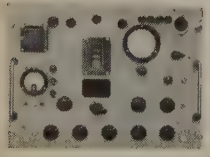
A highly miniaturized receiver-transmitter for missile applications to facilitate radar tracking. Supplied with power supply, cable and antenna (not shown).



"X" BAND TEST EQUIPMENT

TEST SET BHS (AN/UPM-10A)

A portable microwave signal generator for testing and adjusting beacon equipment and radar systems operating in the range of 8500 to 9600 MC. Measures power and frequency of external signals. Supplies pulse-modulated, square-wave-modulated or unmodulated signals of known power and frequency. Also supplies frequency-modulated signals.



NEW! MODEL BDX FOR GREATER ACCURACY

Greater frequency accuracy (±1 mc from 8500 to 9600 mc). Greater power level accuracy (±1.5 dbm without correction curves). Repetition rates high enough to measure recovery time with assurance (up to 50,000 PPS). Operates with or without an auxiliary trigger. More rugged and dependable. The only complete signal tester for beacon work.

GENERAL COMMUNICATION COMPANY

681 Beacon Street, Boston 15, Massachusetts

See us in booth 3063, IRE Show

Whom and What to See at the Radio Engineering Show

(Continued from page 182A)

Comco Plastics, Inc., Booth 4238
97-24 Albert Rd.,
Ozone Park 17, N. Y.
Arthur E. Herman, Joseph Steele
Precision Plastic Parts for Electronic, Nuclear & Aircraft Components and Assemblies

Commercial Plastics & Supply Corp., Booth 4240
630 Broadway
New York 12, N. Y.
Arthur E. Herman, Joseph Steele
Plastic Sheets, Rods and Tubes.

Communication Accessories Co., Booths 3908-3910
110th & 71 Highway
Hickman Mills, Mo.
▲ Edward J. King, Jr., George E. Guide, ▲ Wayne S. Bonebright, ▲ "Buck" Jones, Cliff W. Black
Missile Power Supply and Subminiature Mechanical Filter Toroidal Components. Inductors, Transformers, Tuned Circuits, Electrical Wave Filters, Discriminators, Magnetic Amplifiers & Saturable Reactors. Collins Industrial Components—Mechanical Filters, Ferrite Cores, Heat Reducing Tube Shields, Precision Tuned Oscillators, AutoTunes & Laminated Transformers.

Compagnie Generale De Metrologie (Metrix), Booth 3120
230 Bayard Road
Upper Darby, Pa.
Martin E. Gerry
Test equipment, multimeters, panel meters.

Computer Control Company, Inc., Booth 1322
92 Broad Street
Wellesley 57, Mass.
William Wolfson
Live display of variety of digital plug-in printed circuit modules. All packages are thoroughly engineered for complete inter-compatibility to permit system usage directly and simply.

Computer Instruments Corp., Booth 1814
92 Madison Ave.
Hempstead, L.I., N.Y.
Henry Segal
Precision Potentiometers.

Computer-Measurements Corp., Booths 1620-1622
5528 Vineland Ave.
North Hollywood, Calif.
J. K. Rondou, ▲ R. E. Lovejoy, E. C. Titcomb
Digital Printer. *Deviation Meter, Universal Counter-Timers, Frequency Counters, Flow Indicators, Time-Function Translators, Time Interval Meters, Preset Controllers, Totalizing Counters, Standard and *Low-Power Decades.

Condenser Products Co., Booth 2232
Div. New Haven Clock & Watch
140 Hamilton St.
New Haven 4, Conn.
Richard J. Hesse, ▲ Herbert A. Haworth, ▲ Thomas J. Murphy, William Gentry, James R. DeSanty
Uncased polystyrene capacitors for computor applications.

Conrad, Inc., Booth 3834
141 Jefferson St.
Holland, Michigan
C. Conrad, R. Alden, K. Dadd, C. Way
A combined Temperature and Vibration Test Chamber, Model FBV-8 with a range of −100° F. to +500° F.

(Continued on page 186A)

* Indicates new product.
▲ Indicates IRE member.



DP-DT—"Battery-Line" changeover type



3P-DT Detent Optional



SP-DT 0.75 amp. Spring-return



SP-ST—Pushbutton, Momentary contact



3-Position 0.5 amp. Detent





4-Position with detent



SP-DT—Plunger type. Spring return

HOW TO ADD TO THE Saleability OF MANY ELECTRICAL PRODUCTS

...Instruments
...Appliances
...Small Motors
...Radio, TV,
Audio Equipment





SP-DT 4 gangs, common base

TO ENGINEERS, Stackpole Slide Switches in more than a dozen inexpensive types offer many interesting design possibilities for improving product performance.

TO BUYERS of today's instruments and appliances, the convenience of unique and attractive modern switching arrangements exerts strong sales appeal that far exceeds the modest cost involved.

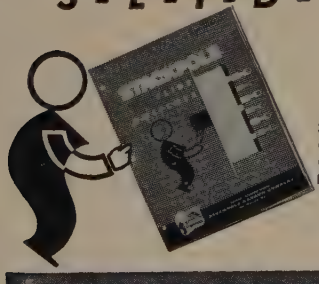
Stackpole Slide Switches cover the ½ to 3 ampere range. They vary from simple ON-OFF units to types that provide complicated inter-circuit switching in minimum space—often with less costly mountings than conventional switches. *Electronic Components Division,* STACKPOLE CARBON COMPANY, *St. Marys, Pa.*



SP-DT 3 amps. Detent

STACKPOLE

S-L-I-D-E SWITCHES





3-Position 0.5 amp. Detent

***New* SLIDE SWITCH DATA**

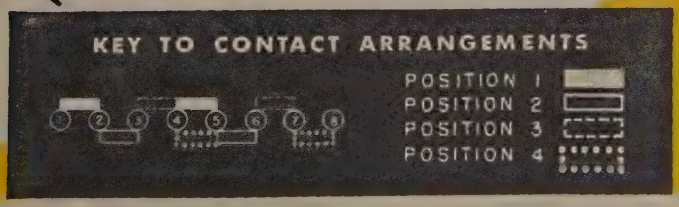
Stackpole Bulletin RC-10D — just out — gives complete ratings, dimensions, modifications, and other specifications for all standard Stackpole Slide Switches. Write for your copy or see your local Stackpole representative

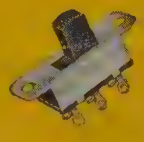


SP-DT 1 amp. Detent

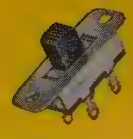


DP-DT 3 amps. Detent





DP-DT 0.5 amp. Detent



3-Position 3 amps. Detent

TRU OHM TOP PRODUCTS

America's TOP Line "TRU-RIB" VITREOUS ENAMELED RESISTORS



Circuits requiring units of high current and wattage ratings at relatively low resistance values need TRU-RIB RESISTORS. They are especially adaptable to starter duty, but can be used in a wide variety of continuous duty applications.

Available up to 1500 maximum watts. Special units can be designed for specific applications.

Order from TRU-OHM . . . the world's largest producers of wire-wound resistors.

We always ship on time . . . and we expedite for you

TRU-OHM Power Rheostats

Available from 25 to 150 watts . . . from stock or to your specifications.



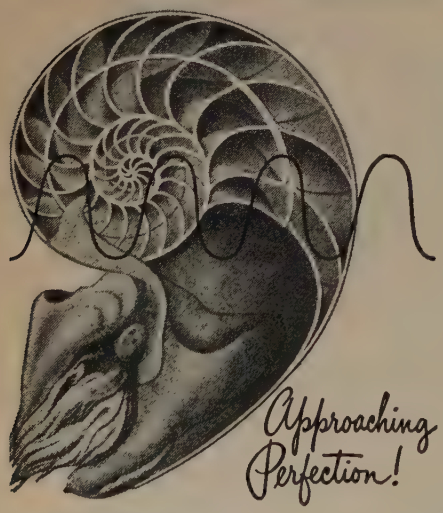
TRU-OHM PRODUCTS

Division of Model Engineering & Mfg., Inc.

General Sales Office: 2800 N. Milwaukee Ave., Chicago 18, Ill.

Factory: Huntington, Indiana

MANUFACTURERS: Power Rheostats, Fixed Resistors, Adjustable Resistors, "Econohm" Resistors, "Tru-rib" Resistors



MODEL 1200
SINE WAVE GENERATOR

Less than 0.1% distortion at any amplitude or frequency. 1 cps to 1 mc in 6 decades, plus overlap. 600 ohms constant output impedance. Many other exceptional features. Small, portable — 23 pounds. Complete data on request. $265.00, FOB Factory.



DONNER SCIENTIFIC COMPANY

805 Galindo Street
Concord, California

The nautilus exhibits a perfect logarithmic spiral (from Cook, T. A. Curves of Life, New York, Henry Holt & Co., 1914).

Whom and What to See at the Radio Engineering Show

(Continued from page 184A)

Consolidated Electrodynamics Corp., Booths 3223, 3225
300 North Sierre Madre Villa
Pasadena 15, Calif.
F. G. McGavock
Type 2203-03 Pirani Vacuum Gauge; Evapor-Ion Vacuum Pump; Primary Pressure Standard, Type 6-201.

The Constanta Co. of Canada Ltd., Booth 3919
280 Regina Ave.
Montreal, P.Q., Canada
Walter J. Bastanier
Constanta *RESISTORS*, precision, high stability, deposited carbon. Sizes: 2 Watt to Subminiature 1/50 Watt. Also with insulated ends. Tolerance to ½%. Meet all tests.

L. L. Constantin & Co., Booths 3801, 3803
Franklin Ave. at New Jersey H'way
Lodi, N. J.
Wm. J. Casey, Chas. Yocum, Stephen C. Taber, L. Smolen, D. Grant, J. Comer, F. Buoro, F. Dente, A. Dudas, R. Roussey, G. Podeyn, S. Schmidt, R. Ragon, R. Kennedy, T. Kennedy
Vacuum-tight glass-to-metal sealed "all-in-one" unit header assemblies, single terminals, multipin headers, connectors, and high compression and kovar seals for relay, transformer, semiconductor, capacitor, crystal holder and other applications.

Continental Carbon, Inc., Booth 2209
5221 Greene St.
Philadelphia 44, Pa.
W. M. Wood
Resistors, potentiometers, slide switches.

(Continued on page 190A)

PANELOC
ROTARY LATCHES

. . . *for use on hinged or removable parts, such as inspection doors, access panels, etc.*

. . . *engineered to save*
. SPACE
. WEIGHT
. TIME
. COST

. . . *designed to provide*
MAXIMUM ACCESS

. . . *with*
ENTIRE LATCH
IN ONE PANEL

Booth #4007, IRE Show

SCOVILL
MANUFACTURING CO.
Waterbury 20, Conn.

Transitron

Silicon

Transitron's diodes, voltage regulators and rectifiers are designed to operate over wide environmental extremes and meet the many varied requirements of electronic circuitry. Reliability is assured through hermetic sealing and exacting manufacturing standards.

Transitron's silicon units have established a record of dependability in such critical applications as guided missiles and jet aircraft. They feature low inverse leakages and high voltage operation and are recommended for high temperature applications where germanium and selenium are unreliable.



- Current ratings up to 2 amps
- Superior regulating qualities
- Rugged construction
- Small size
- Axial mounting

Send for Bulletin TE-1352

VOLTAGE REGULATORS

	Type	Voltage Range	Dynamic Resistance	Maximum Current @ 25°C (ma)	Maximum Current @ 125°C (ma)
Subminiature	SV-6	5.2 - 6.4	20	40	8
	SV-9	7.5 - 10.0	15	25	5
	SV-15	13.5 - 18.0	120	14	3
	SV-24	20.0 - 27.0	300	10	2
Miniature	SV-805	5.2 - 6.4	20	120	24
	SV-808	7.5 - 10.0	15	75	15
	SV-815	13.5 - 18.0	120	40	8
	SV-824	20.0 - 27.0	300	27	5
				(amps)	(ma)
Power	SV-905	5.2 - 6.4	.7	1.6	400
	SV-908	7.5 - 10.0	.8	1.0	250
	SV-915	13.5 - 18.0	3.0	.6	150
	SV-924	20.0 - 27.0	8.0	.4	100



"Leadership in semiconductors"



Germanium Diodes | Transistors | Silicon Diodes | Silicon Rectifiers



INTERNATIONAL

A Division of Columbia Broadcasting System, Inc. is pleased to announce its expansion into the field of television, broadcasting, and communication equipment.

Manufacturers who wish to increase their sales abroad are invited to contact us with respect to foreign representation.

CBS International now exports the following items to all markets of the free world:

CBS Radio and Television Picture Tubes

CBS Transistors, Diodes, and Semi-Conductors of all Types

CBS Columbia Phonographs and Records

CBS Magnetic Recording Tape

CBS INTERNATIONAL
485 Madison Avenue, New York City 22, N. Y.
PLaza 1-2345

Whom and What to See at the Radio Engineering Show

(Continued from page 186A)

Continental Diamond Fibre, Div. of the Budd Co., Inc., Booths 4223, 4224
16 Chapel St.
Newark 48, Del.

Olan Thomas, F. W. Jahns, Jr., Allen W. Ballard

New products of Teflon and Silicone. An extensive line of Electrical Insulating Products made from: Diamond Vulcanized Fibre, Dilecto, Celoron, Vulcoid, and Micabond.

Continental Electric Co.
6 North Michigan Ave.
Chicago, Ill.
Booth 1822

E. H. Glaeser, H. Hodgeson, L. R. Oswald, J. De Vleshower

Cetron-Taylor Electronic Tubes. Rectifiers, photoelectric tubes, thyratrons. Transmitting triodes.

Coors Porcelain Company, Booth 4006
Golden, Colorado

Joseph Coors, ▲ William H. Johnson, Charles S. Ryland, Coulson Hageman

Not new—Ever Improved Ceramic.

Cornell-Dubilier Electric Corp.
333 Hamilton Blvd.
South Plainfield, N. J.
Booths 2725-2727

▲ William Bailey, ▲ William Robinson, Eugene Frekko, William Otto, ▲Ted Rosser, Lou Alexander.

MINIATURIZED CAPACITORS and Capacitors of every description including Power Factor Improvement and Interference Filters—Industrial and Railroad Inverters—Automotive and Industrial Vibrators—Antenna Rotors—Printed Circuitry.

Corning Glass Works, Booths 2404-2408
Corning, N. Y.

Fred R. Rector

Glass capacitors, resistors, delay lines.

Cowan Publishing Corp., Booth 4031
300 West 43rd St.
New York 36, N. Y.

▲ S. R. Cowan, R. A. Cowan, J. N. Schneider, Wayne Greene, ▲ Samuel L. Marshall, Ray Korn

CQ—The Radio Amateurs' Journal; Service-Dealer & Electronic Servicing; Single Side Band Techniques; Mobile Handbook; Video Speed Servicing Systems; TV Schematics; Magazines & Periodicals.

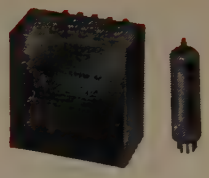
Cox & Co., Inc., Booth 2741
115 East 23rd St.
New York 10, N.Y.

Duncan B. Cox, John L. Cox, H. M. Brusman, R. W. Ayer, J. A. Reagan, L. C. Sanford

OVEN FOR TRANSISTOR AMPLIFIER High-performance 225° F transistor oven: stabilizes from minus 70° F (or any higher temperature) in only two minutes. Over 2,000 other heater applications approved. 250,000 heaters in use.

(Continued on page 192A)

You can join IRE professional groups at the Waldorf-Astoria or the lobby of the New York Coliseum. See pages 90A-91A for complete information on these groups.



MEET THE

MIGHTY MIDGET

OF AIRCRAFT FIRE POWER

This new TRANSISTORIZED CONTROL AMPLIFIER weighs only 11 ounces...but it is a vital control element in the voltage regulation of an entire aircraft fire control system. Developed as part of an integrated power supply, the "MIGHTY MIDGET" operates from —65° to +125° C...reduces ripple to less than 50mv peak-to-peak...is adaptable to voltages of ±50 to ±1000...controls voltage regulation to ±1%. Here is another example of Packard Bell's skill in developing lighter, more efficient airborne equipment... another result of more than 30 years of electronic leadership.

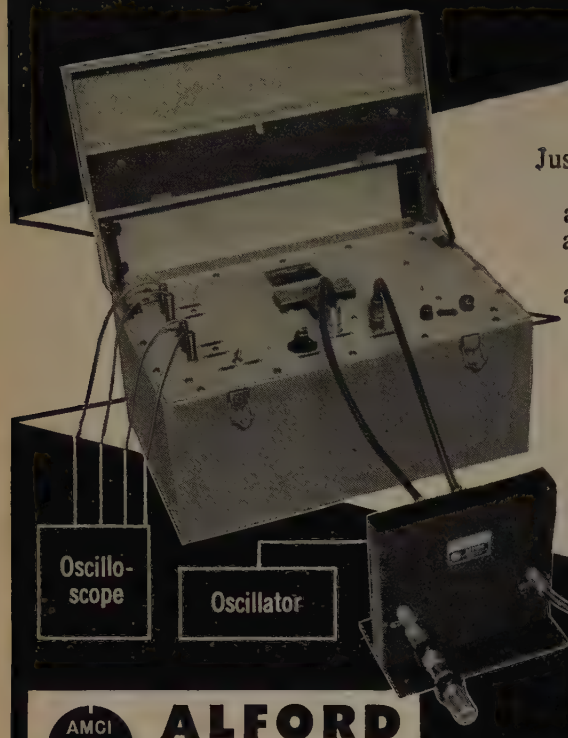
See it at the New York IRE SHOW... booths 3705–3707.

PACKARD BELL ELECTRONICS

TECHNICAL PRODUCTS DIVISION

Los Angeles 64, California

NEW AMCI AUTOMATIC IMPEDANCE PLOTTER



For Lab or Production Testing

Just turn the oscillator dial, manually or by a motorized sweep drive, and the impedance curve of load Z is traced on a regular or an expanded Smith chart. Either an oscilloscope or a two-axis recorder can be used.

See this equipment in operation at Booth 1623, I.R.E. Show

AMCI **ALFORD** *Manufacturing Co., Inc.*
299 ATLANTIC AVE., BOSTON, MASS

Model 11-P . . . . . 200 mc — 960 mc.
Model 11-Q . . . . . 30 mc — 400 mc.

INSTRUMENTS — ANTENNA SYSTEMS — COMPONENTS — AIR NAVIGATION AIDS

NOW ADDED TO OUR STANDARD LINE!
STOCK NYLON BOBBINS FOR POT & CUP CORE APPLICATIONS



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- WRITE FOR NEW CATALOG

American Molded Products Co.
2729-39 W. CHICAGO AVE. PHONE: ARmitage 6-3235 CHICAGO 22, ILL.

NEW! **Magnivider**



Magnetically Controlled Counter-Divider

- Using a "ladle-bucket" principle, magnetic cores in the unique Magnivider circuit set a new high of reliability and ruggedness wherever counting, scaling or frequency division are required.
- Self-contained Magnivider plug-ins are ideal for your new equipment designs. One tube Magnividers offer many distinct advantages over conventional four tube counters. With scaling ranges from 9 to 11, Magnividers have a wide range of application.
- Write for our technical bulletin 145 to obtain complete information.
- See the Magnivider at our Booth 3944, 3rd Floor, IRE Convention.

MAGNETICS RESEARCH COMPANY
255 GROVE ST.
WHITE PLAINS, N.Y.

Whom and What to See at the Radio Engineering Show

(Continued from page 190A)

Craig Systems, Inc.
90 Holten Street
Danvers, Mass.

Booth 1325

▲ J. Roy Wolfskill, Perry L. Nies, Stephen M. Freidrich, John A. Winskowicz, Edward O'Callahan, Irving W. Lovell, Ernest Chase, Stuart R. Hyans, Michael MacDonald



HELICOP-HUT radio communication station—a self-contained transportable and mobile system; reusable transit cases for electronic equipment; spare parts cabinets; guided missile carriers; relay racks.

Cramer Controls Corporation, Booths 2431, 2433
Centerbrook, Conn.

James Coppage

Timing devices, timing motors, time meters.

Crosby Laboratories, Inc.
Box 233, Robbins Lane
Hicksville, L. I., N. Y.

Booth 1415

▲ Murray G. Crosby, ▲ Barton C. Coffman, Cloyd N. Harshbarger

*New line of single-sideband communications equipment, featuring a new frequency stabilized S.S.B. signal generator, with improved S.S.B. receiving and transmitting equipment, including a diversity combiner for S.S.B. reception.

Crucible Steel of America, Booths 2829-2831
Henry W. Oliver Bldg.
P. O. Box 88
Pittsburgh 22, Pa.

T. M. Rutter

Alloy tubing, magnets, alloys, stainless steel.

Cubic Corp.
5575 Kearny Villa Rd.
San Diego 11, Calif.

Booth 1723

▲ William J. Thompson, ▲ Louis G. Dameson, ▲ James G. Tabler, ▲ William Boyd



Cubic model 504 completely transistorized, self-powered transistor curve tracer presents eight-curve family for immediate evaluation of PNP and NPN junction transistors.

(Continued on page 196A)

ESIGN AND COST PROBLEMS

Deposited Carbon Resistors

New molded resistor line providing a means of obtaining long-term stability up to 100 megohms with savings in cost and bulk.

- 1/8, 1/4, 1/2, 1 and 2 watt ratings
- excellent load life characteristics and resistance to aging
- conservatively rated at 70° C. ambient

Low Range BW Wire Wound Resistors

Now mass produced at low cost for transistor applications where the low value and stability of a wire wound resistor is an important factor. Ruggedized unit to withstand rigors of modern installation techniques.

- fully insulated
- values from 0.24 ohm to 10 ohms



VISIT BOOTHS 2821—2823—2825

Components Floor
RADIO ENGINEERING SHOW
March 18 to 21

sulated Composition Resistors • eposited and Boron Carbon ecistors • Power Resistors • oltmeter Multipliers • Ultra HF nd Hi-Voltage Resistors

Wherever the Circuit Says

ow Wattage Wire Wounds • esistance Strips and Discs • elenium Rectifiers and Diodes • ermetic Sealing Terminals • sulated Chokes • Precision Wire Vounds • Potentiometers

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IRC PLANTS—Asheville, N.C. • Boone, N.C.
Burlington, Iowa • Philadelphia, Pa.
Hycor Division, Sylmar, California
Circuit Instruments Inc., St. Petersburg, Fla. (subsidiary)
Hycor Company, Inc., Vega Baja, P.R. (subsidiary)

INTERNATIONAL RESISTANCE COMPANY

Dept. 371, 401 N. Broad St., Philadelphia 8, Pa.
In Canada: International Resistance Co., Ltd., Toronto, Licensee

Send complete information on ☐ Selenium Dual Diodes, ☐ Delay Lines, ☐ Hermetic Sealing Terminals, ☐ Power Resistors, ☐ Molded Deposited Carbon Resistors, ☐ BW Wire Wound Resistors

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Company _____

Address _____

City _____ State _____

BOOTH 4018—IRE SHOW—WILL DISPLAY. . . . .

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LEACH & GARNER CO.

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Precision products of precious metals include slip rings, micro brushes, contact rivets, buttons, spring contacts and bar contacts. Complete engineering and tooling facilities for custom manufacturing. Prompt quotations and recommendations upon inquiry.

INDUSTRIAL DIVISION
GENERAL FINDINGS AND SUPPLY COMPANY

Electronic and Electrical Components

We build our business on prompt deliveries at competitive prices.
SALES OFFICES:
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Whom and What to See at the Radio Engineering Show

(Continued from page 192A)

James Cunningham Son & Co.
33 Litchfield Street
Rochester 8, New York
Booth 2839

▲ A. Vincent, ▲ K. Enslein, F. Cunningham, ▲ F. Bradley, Jr



Crossbar Scanner

Crossbar Scanner and Crossbar Scanning and Monitoring Systems. Complete line of Crossbar switches for data handling, monitoring, telemetering, test equipment, video, radar delay line switching and many other uses. Low cost crossbar scanner, a self contained instrument capable of scanning 200 points sequentially in response to a contact closure.

Curtis Development & Mfg. Co.
3266 North 33rd St.
Milwaukee 16, Wis.
Booth 2827

Robert E. Miller, John A. Eschweiler

CURTIS Terminal Blocks

See our new line of Terminal Blocks with Push-on Connectors. Also exhibiting new terminal block up to 250 Amperes.

Curtiss-Wright Corp., Electronics Division, Booth 1327
631 Central Avenue
Carlstadt, N. J.

▲ Dr. P. Christaldi, ▲ K. Urpadi, ▲ J. Sauer, ▲ A. Bastian, ▲ G. Schoenwald

*Version of the C-W Dynamic Capacitor Electrometer, Distortion Eliminating voltage regulator, "snapper" time delay relays, nuclear reactor controls, radiation safety survey meter.

Cutler-Hammer, Inc., Booth 3931
315 N. 12th St.
Milwaukee 1, Wisconsin

H. K. Melzer

Small motor switches and power relays—commercial & military types.

Dage Electric Company, Inc., Booth 2633
67 N. 2nd Street
Beech Grove, Indiana

Calvin J. Zehr, C. P. Ellis, ▲ Al Strickland, Karl Wallace

Miniature "DM" Series Coaxial Cable connectors—¼ the size ⅓ the weight of standard. BNC Series Gold Plated Environmental resistant.

(Continued on page 198A)

The first digit of each booth number indicates the floor on which the booth is located.



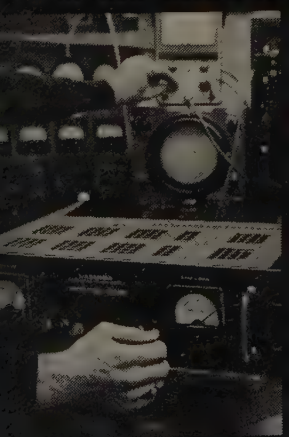
QUALITY CONTROL assures you of long, dependable service from these assembly-line-produced power supplies.



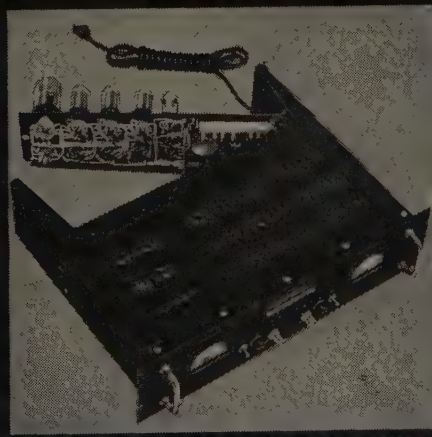
HERMETIC SEALING PROCESS provides for complete quality control. Lambda makes all its own transformers.



MECHANICAL INSPECTION at every relevant point means trouble-free operation for you.



ECTRONIC INSPECTION designed to provide consistent quality and eliminate in-service down-time.



TYPICAL NEW LAMBDA "COM-PAK" MODEL (200-400-800 MA units) occupies a minimum amount of space, delivers maximum performance, is easy to service and maintain.

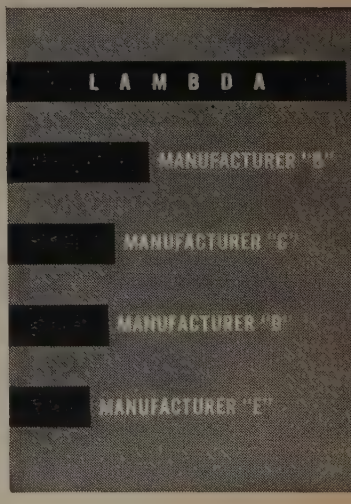
FOR THE THIRD CONSECUTIVE YEAR

ENGINEERS RATE LAMBDA FIRST

in all Power Supply Surveys

Every independent study of power supply preferences has shown an overwhelming vote for Lambda. In the most recent survey, made by a leading electronics publication, engineers who specify power supplies choose Lambda by more than 2½ times over the next identified manufacturer. This is the greatest margin of preference yet. Here is additional proof that the more opportunities users of power supplies have to try Lambda equipment for themselves, the more they recognize the superiority of these outstanding units.

We suggest that you inspect Lambda power supplies in use in your own area. We will be happy to provide names of nearby users. Ask the candid opinion of the men who work with this precision-engineered equipment daily.

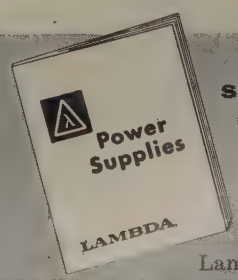


"See the new Lambda Com-Pak series at the IRE Show. New, space saving, 200 MA, 400 MA, 800 MA and 1.45 amp models. Be sure to stop by Booths 2436-2438."

LAMBDA ELECTRONICS CORP.

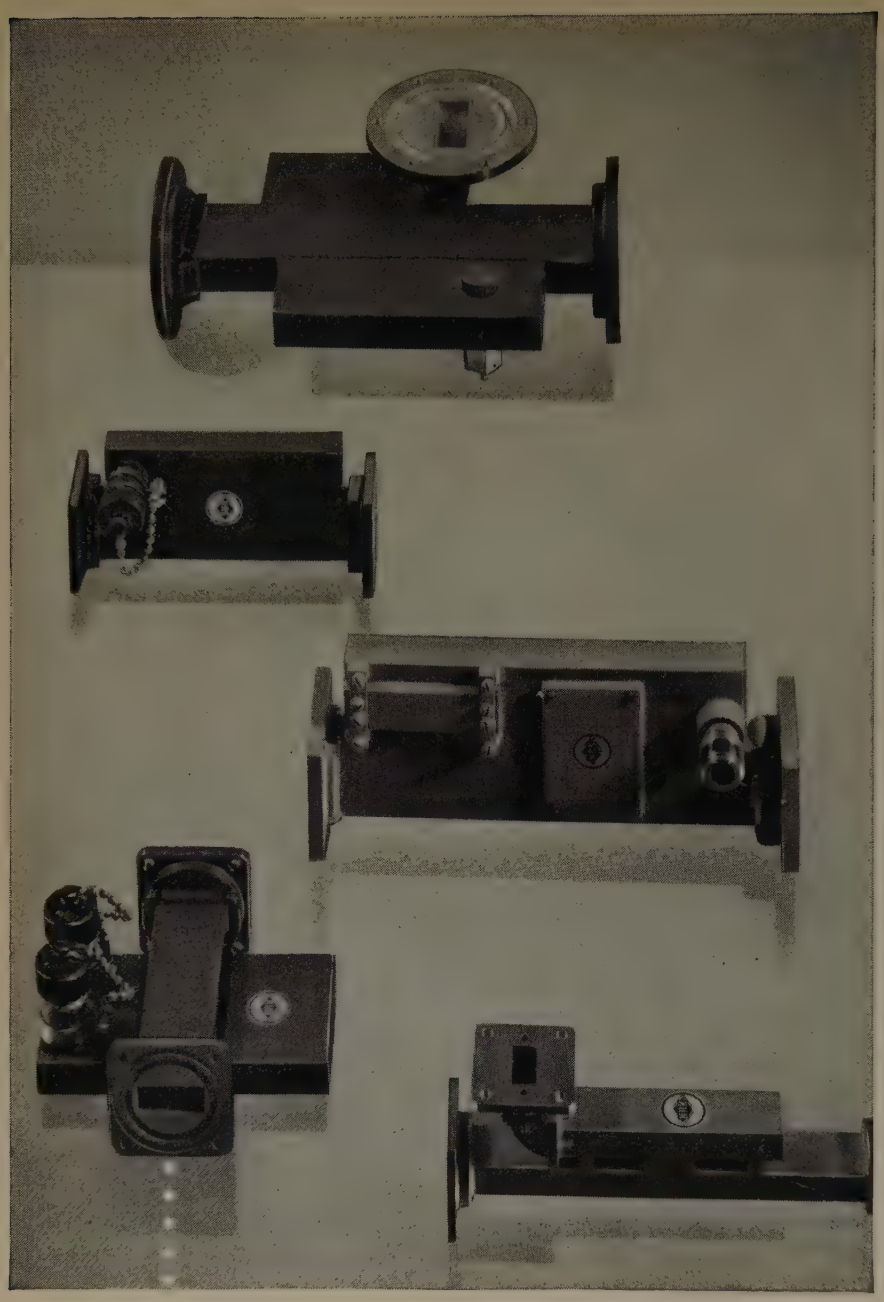
The first name in power supplies

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Just off the presses. Illustrations and specifications for the complete line of Lambda Regulated D.C.



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New York
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4601 W. Addison St., Chicago 41, Ill.
Eastern Sales Office: Box 445, Westfield, N. J.
West Coast Representatives: Tubergen Associates, 2232 W. 11th St., Los Angeles 6, Cal.

NRK

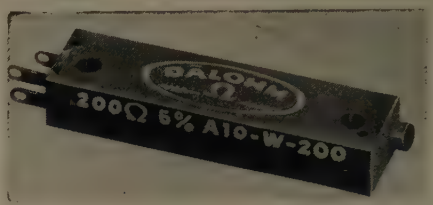
Microwave Assemblies, Radar Components and Precision Instruments... manufactured and designed to your specifications.

Whom and What to See at the Radio Engineering Show

(Continued from page 196A)

Dale Products, Inc.
P. O. Box 136, Columbus, Nebraska
Booths 2742, 2744

▲ George Risk, J. Matejka, R. H. Engstrom, I. E. Gates



Spearheading the DALOHM precision miniaturized resistor and potentiometer display is the Mil-E-Trized A10-W Trimmer; a high temperature wire wound Trimmer potentiometer surpassing requirements of MIL-E5272A and MIL-R-12934.

The Daven Company
530 W. Mt. Pleasant Ave.
Livingston, N.J.
Booths 2717, 2719

▲ Lewis Newman, ▲ Edward L. Grayson, George Newman, ▲ Richard Newman, ▲ K. K. Garrison, ▲ C. Gordon Jones

400 Cycle RC Networks Sub miniature Ceramic Switches; Audio Video and RF Attenuators; Hermetically Sealed Metal Film Resistors; Potentiometers; Voltage Dividers; Rotary Step Type Switches; Solenoid Operated Switches; Precision Wire Wound Resistors; RC Networks; 400 Cycle Network, Vacuum Tube Voltmeters; Transmission Measuring Equipment.

The Davies Laboratories, Div. Minneapolis Honeywell Regulator Co., Booth 3118
4705 Queensbury Road
Riverdale, Maryland

Mr. John M. Magida, Mr. Boyd D. McKnight, ▲ Mr. Irving S. Oscar, Mr. Milton G. Lindgren, Mr. Robert G. Hopwood

*Missile Tape Recorder—small—compact—rugged—capable of in-flight recording under extreme environmental conditions. Also *Laboratory Type Transport capable of handling 14" reels.

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Show issue of SERVICE: The Technical Journal of The Television-Radio Trade.

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Booths 2907-2915 & 1215-1221

Howard J. Warnken, John E. Thomas, Leslie E. Daniels, John Cornell, Marty Kaplan, Harold Hux, John O'Neill, John Ryan



A capacitance Bridge; Capacitance Accuracy ±0.1% or ±0.2% m.m.f.—Dissipation factor ±2.0% or .0001; Also do not miss our Memory Plane.

(Continued on page 200A)



March 1956
Breadboarding of Circuitry

May 1956
Testing Completed Breadboard

July 1956
Engineering Model

September 1956
Operating Prototype

IDEA TO PROTOTYPE ... in just 7 months!

Lewyt cuts delivery time for complex electronic equipment

In developing complex electronic systems for the military, TIME is often the most critical factor. The gap between idea and volume production must be constantly narrowed.

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Meeting all the applicable RETMA Test Standards for molded mica units, these unique dipped-mica capacitors offer the following outstanding features:

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Whom and What to See at the Radio Engineering Show

(Continued from page 198A)

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Decade switched: oscillators, sweep generators, crystal control signal generators, high-frequency counter-converters.

(Continued on page 202A)

* Indicates new product.

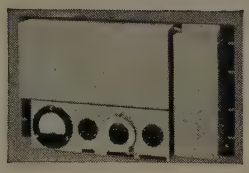
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JK PRODUCTS



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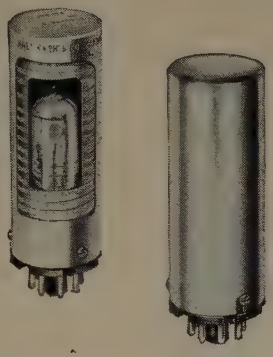
SULZER FREQUENCY STANDARD



JK Sulzer Frequency Standard: For your most precise laboratory measurements, the JK SULZER 1 megacycle Frequency Standard provides stability of better than 1 part in 10^9 per day. Frequency is variable over a range of 0.9 cycles or more, and capable of being reset to 5 parts in 10^{10}.

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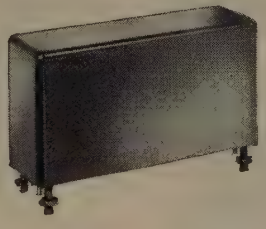
JK TRANSISTOR OSCILLATOR



JK Thermystal: An advanced-design frequency control unit combining plug-in simplicity with extreme precision. *Frequency stability:* 30 to 900 kc, ±.0001%; 1000 kc to 150 mc, ±.00005%.

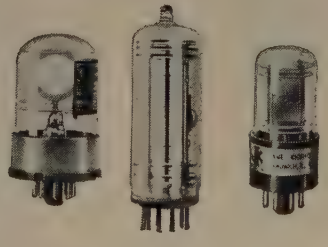
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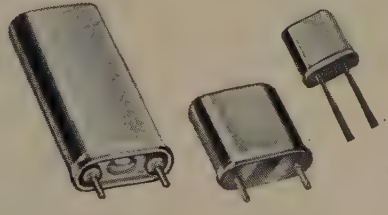
JK Crystal Filters: Compact, rugged, hermetically-sealed and stable, JK CRYSTAL FILTERS (band pass filters) have a *Frequency Range:* 1 mc to 17.5 mc., and are available for special filtering purposes to 150 mc. *Band Width* at 6 db: 0.01% to 4% of nominal on all frequencies, and up to 12% for certain frequencies.

JK GLASLINE CRYSTALS



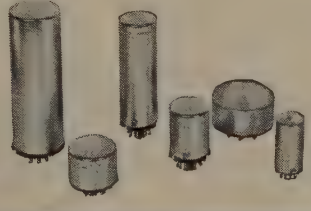
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JK MILITARY TYPES



JK Military Types: Hermetically-sealed, JK MILITARY TYPE CRYSTALS are metal-cased and in *Frequency Ranges:* 16 kc to 100 mc.

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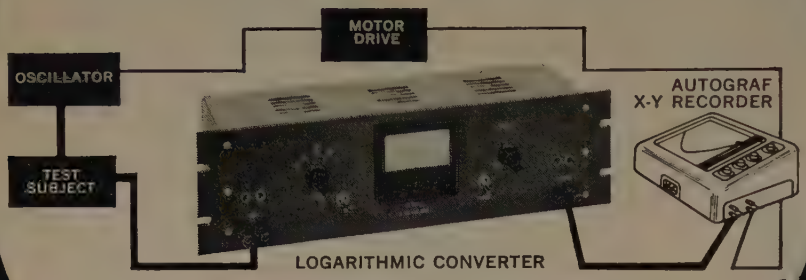


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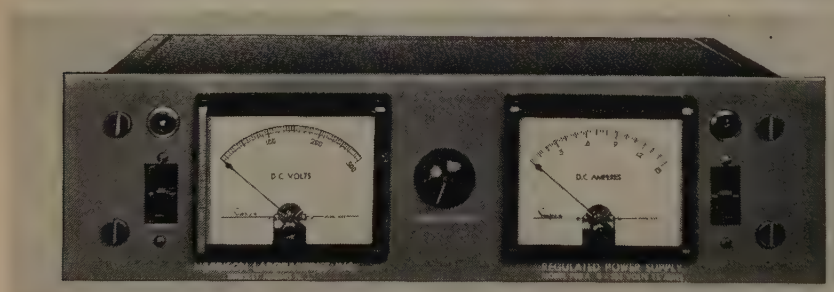
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OUTPUT VOLTAGE VARIATION FROM NO LOAD TO FULL LOAD: 0.01 volts
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DIMENSIONS: 5¼" H, 19" W, 17½" D (Standard relay rack mounting)
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(Continued from page 200A)

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Walton DeVerter, Claude Michael



Printed Circuit, Silver Solder, and 21 other standard models of Solder Pots. Deluxe and Standard Units with and without Thermostats.

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Booths 3911-3913

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Manufacturer of "High-Power" transistors (illustrated), automobile radios, radio tuners, speakers, automatic controls.

(Continued on page 204A)

* Indicates new product.
▲ Indicates IRE member.



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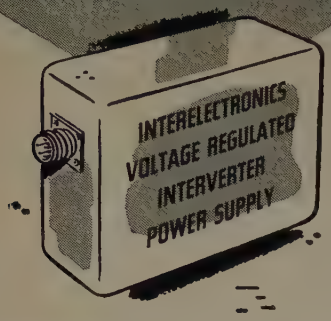
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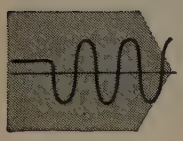
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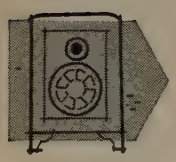
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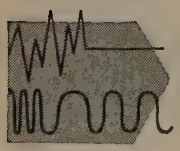




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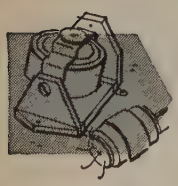
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Interelectronics — first and most experienced in the DC input solid-state power supply field, produces its own solid-state gating elements, all magnetic components, has the most complete facilities and know-how—has designed and delivered more working KVA than any other firm!



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(Continued from page 202A)

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Richard DeMornay, Robert L. Pflieger, Howard Feiner, Ted M. Brown

That NEW Idea

D-B Precision Microwave Equipment

2.6 KMC-90.0 KMC

microwave BUILDING BLOCKS

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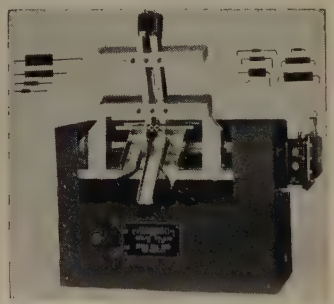
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(Continued on page 206A)

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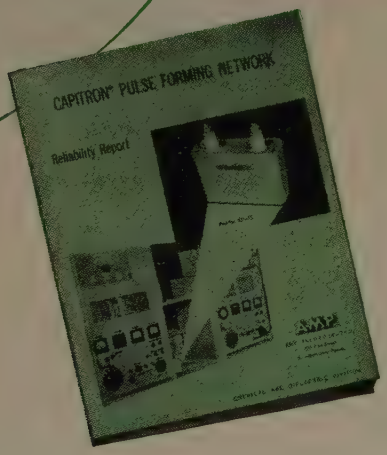
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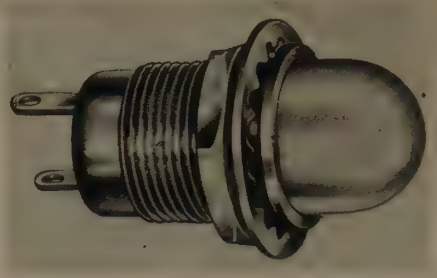
Electra

Whom and What to See at the Radio Engineering Show

(Continued from page 204A)

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* Universal Slotted Line Kit—17 to 5.85 KMC (Interchangeable sections) * Antennas, * Gain Horns. * Rotary Joints, * Diplexers, * Attenuators, Directional Couplers, crystal mounts, stub tuners, Frequency Meters, Line Stretchers, Mixers, * Hybids. * Phase Shifters, Terminations, Transitions, Adapters. * Waterloads, Dummy loads, Klystron Mounts. Waveguide Assemblies, UG Flanges.

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▲ W. B. Hunter, P. H. Kirwin, E. Hall, Jr., J. E. Harvey, J. C. Ike, F. C. Helies

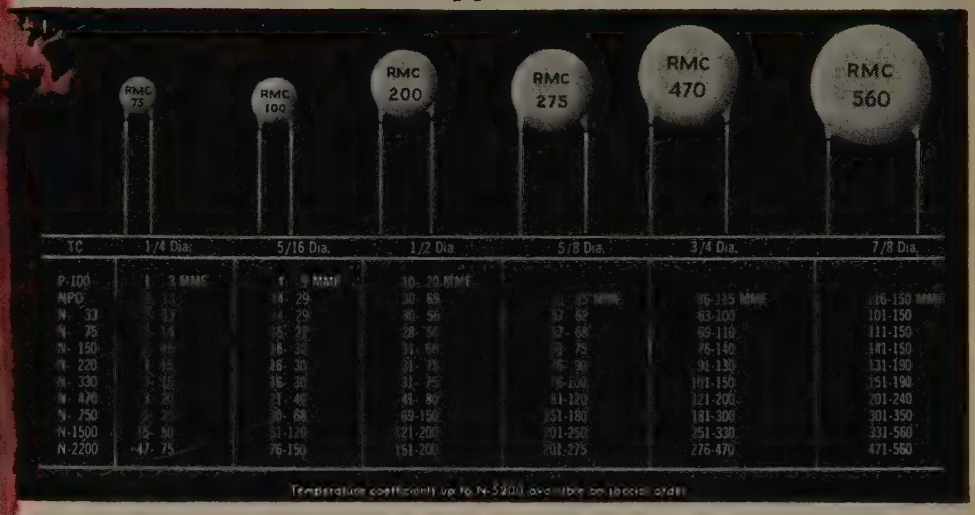
New size 11 resolver, new temperature compensated AC Tachometer.

(Continued on page 208A)

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RMC DISCAPS

Type C



TC	1/4 Dia.	5/16 Dia.	1/2 Dia.	5/8 Dia.	3/4 Dia.	7/8 Dia.
P-100	1- 3 MMF	1- 9 MMF	10- 20 MMF			
NPO	1- 15	14- 29	30- 65	66- 85 MMF	86-135 MMF	136-150 MMF
N- 33	1- 17	14- 29	30- 56	57- 82	83-100	101-150
N- 75	1- 34	15- 27	28- 56	57- 68	69-110	111-150
N- 150	1- 44	16- 30	31- 60	61- 75	76-140	141-150
N- 220	1- 45	16- 30	31- 75	76- 90	91-130	131-190
N- 330	1- 15	16- 30	31- 75	76-100	101-150	151-190
N- 470	1- 20	21- 40	41- 80	81-120	121-200	201-240
N- 750	1- 25	26- 68	69-150	151-180	181-300	301-350
N-1500	15- 50	51-120	121-200	201-250	251-330	331-560
N-2200	47- 75	76-150	151-200	201-275	276-470	471-560

Temperature coefficients up to N-5200 available on special order

SPECIFICATIONS

POWER FACTOR: Over 10 MMF less than .1% at 1 megacycle. Under 10 MMF less than .2% at 1 megacycle.

WORKING VOLTAGE: 1000 V.D.C.

TEST VOLTAGE (FLASH): 1750 V.D.C.

CODING: Capacity, tolerance and TC stamped on disc

INSULATION: Durez phenolic-vacuum waxed

INITIAL LEAKAGE RESISTANCE: Guaranteed higher than 7500 megohms

AFTER HUMIDITY LEAKAGE RESISTANCE: Guaranteed higher than 1000 megohms

LEADS: No. 22 tinned copper (.026 dia.)

TOLERANCES: ±5% ±10% ±20%

These capacitors conform to the RETMA specification for Class 1 ceramic condensers.

The capacity of these condensers will not change under voltage.

In temperature compensating capacitors, RMC Type C DISCAPS are the accepted standard in the electronic industry. Inherent stability provides for rated capacities that will not change under voltage. Type C DISCAPS are rated at 1000 working volts and cost no more than ordinary 600 volt capacitors.

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to 500 Megacycles



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- Full scale volts: .003, .01, .03, .1, .3, 1 & 3
- Freq. range: 0.2—500 megacycles
- Accuracy: 5% full scale to 200 mc
  10% full scale to 500 mc
- No zero drift
- RMS response below 0.1 volt
- High impedance probe: 2.5 mmf
- 52 ohm probe: vswr approx. 1.1 to 500 mc
- Power sensitivity: .02 microwatt
- Calibration in both db and volts
- Lighted meter scale

Model 91B **Price: $375.00**

APPLICATIONS

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- Attenuator loss measurements
- Mixer gain or loss measurements
- Transistor gain measurements at low levels
- Frequency — gain characteristic measurements over 70 db range
- Null indicator
- Filter network loss measurements
- Signal generator output measurements
- General purpose experimental work
- Low level comparison measurements of signal sources and attenuators

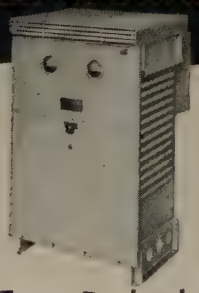
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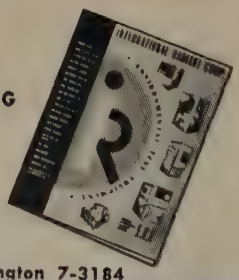
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Whom and What to See at the Radio Engineering Show

(Continued from page 206A)

Dixon Corporation, Booth 4120
Burnside St.
Bristol, R.I.

John A. Crowe

Teflon & Rulon Products—fabricated parts, tubes, tapes.

Donner Scientific Co.
888 Galindo St., Concord, Calif.
Booths 3616-3618

W. K. Rosenberry, ▲Dr. Victor B. Corey, George Bruns, Jr., ▲David A. Taskett

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Douglas Microwave Co., Inc.
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Mount Vernon, N. Y.
Booth 3712

▲R. Harry Douglas, Herb Hendlin, Len Geier

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Dow Corning Corp, Booth 4514
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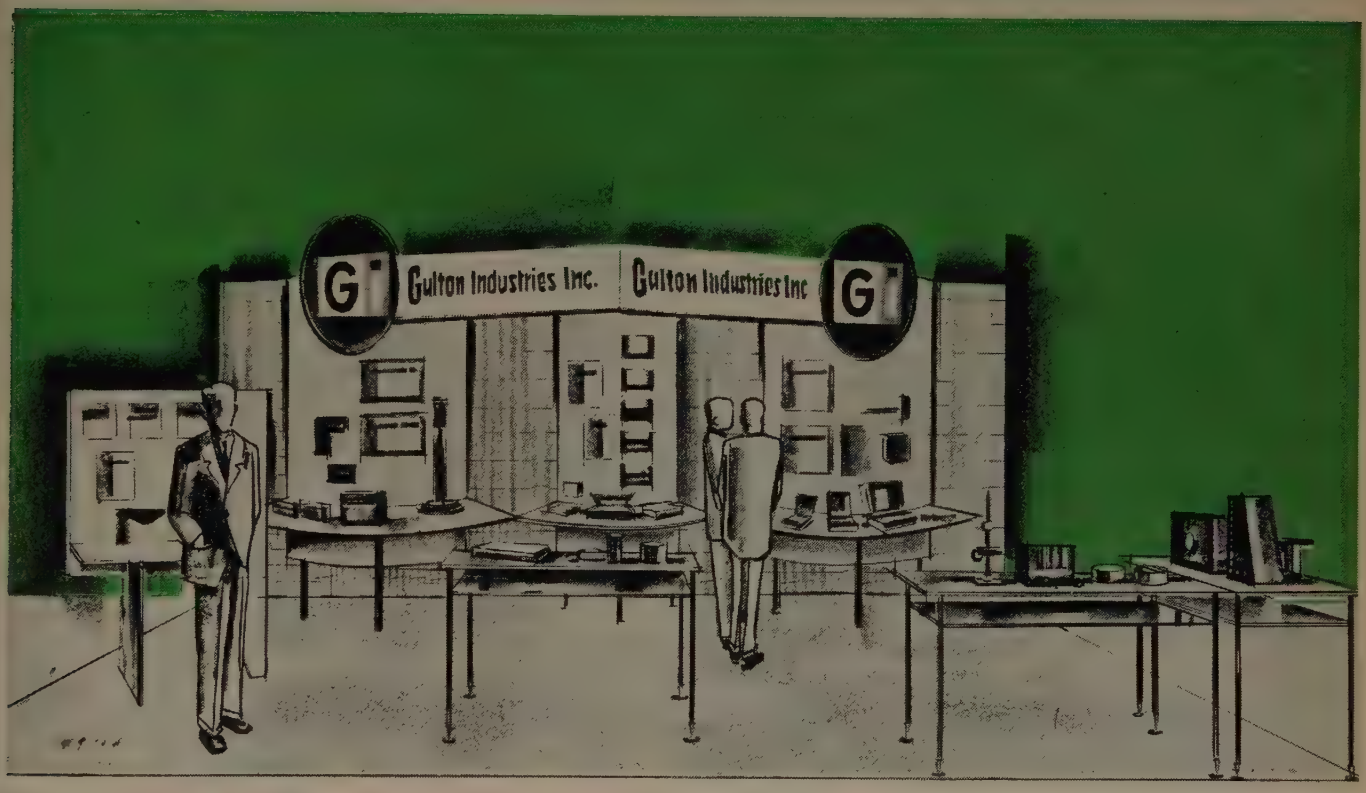
"Taper-Tip" neon indicating light

Indicator Lights for Computors
Lampholders, Indicator Lights, both wired and solder terminal types as well as lampholder for 2-pin lamp.

(Continued on page 210A)

"Whom and What to See at the Radio Engineering Show" will be reproduced in a digest-sized program booklet which will be distributed to every registrant at the Show.

A WORLD OF *New* IDEAS



AT Gulton Industries, Inc. BOOTH #3031-32

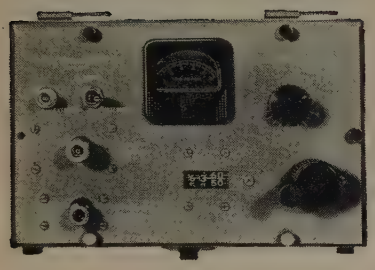
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(Continued from page 208A)

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S. A. Wood, N. P. Norlie, H. J. Hahn, E. W. Swift, R. MacDonald, G. A. Fielding, E. T. Kubilins, H. F. Anderson, E. C. Bennett, T. W. Lindeburgh, A. J. Gottlieb, F. A. Locke, W. Stryker, J. F. Kiessler

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Instruments, cathode-ray tubes and other technical products.

Dumont-Airplane & Marine Instruments, Inc., Booth 2226
15 William St.
New York 5, N.Y.
Hal Dubilier
Capacitors.

(Continued on page 214A)

SYSTEMS

RADAR

1 Antenna
2 Multi-feed rotating joint
3 Waveguide switch
4 Dummy load
5 Directional coupler
6 Mixer-duplexer
7 Local oscillator
8 Ferrite isolator
9 Transmitter klystrons
10 Traveling wave tube drivers

MISSILE

11 Antenna
12 Receiver
13 Transponder

FIELD TEST EQUIPMENT

14 Combination test set
15 Range calibrator
16 VSWR meter



SUPPORT EQUIPMENT

17 RACE (Rapid Automatic Checkout Equipment)
18 System evaluators
19 System performance monitors

DEPOT SUPPORT EQUIPMENT

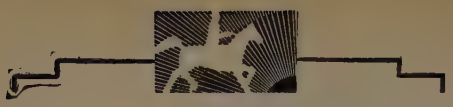
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21 Multi-pulse generator
22 Directional couplers
23 Ferrite isolators
24 Ferrite attenuators
25 Barretter mounts

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(Continued from page 210A)

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(Continued on page 216A)

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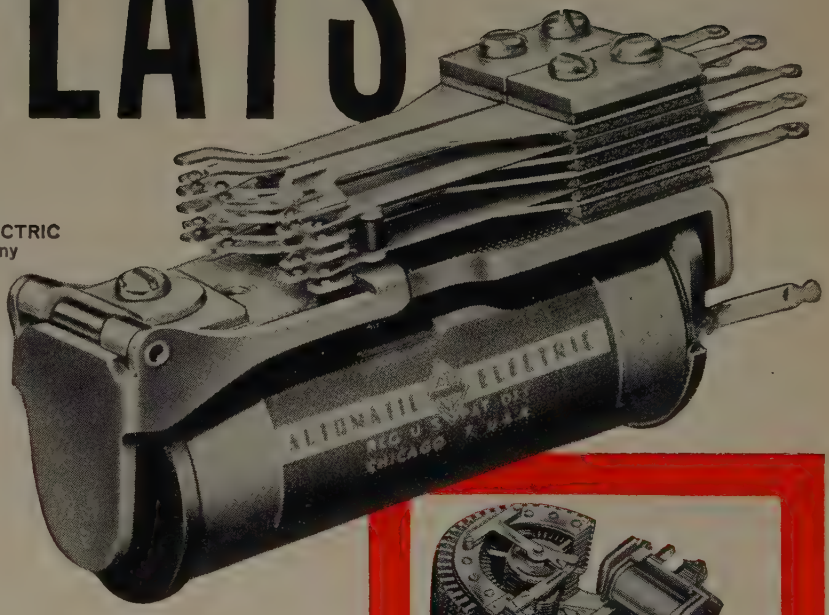
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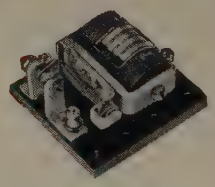
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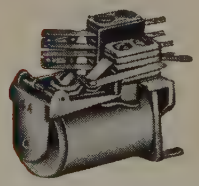
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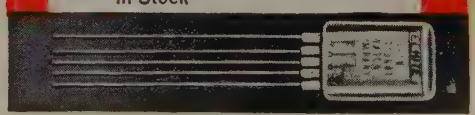
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Whom and What to See at the Radio Engineering Show

(Continued from page 214A)

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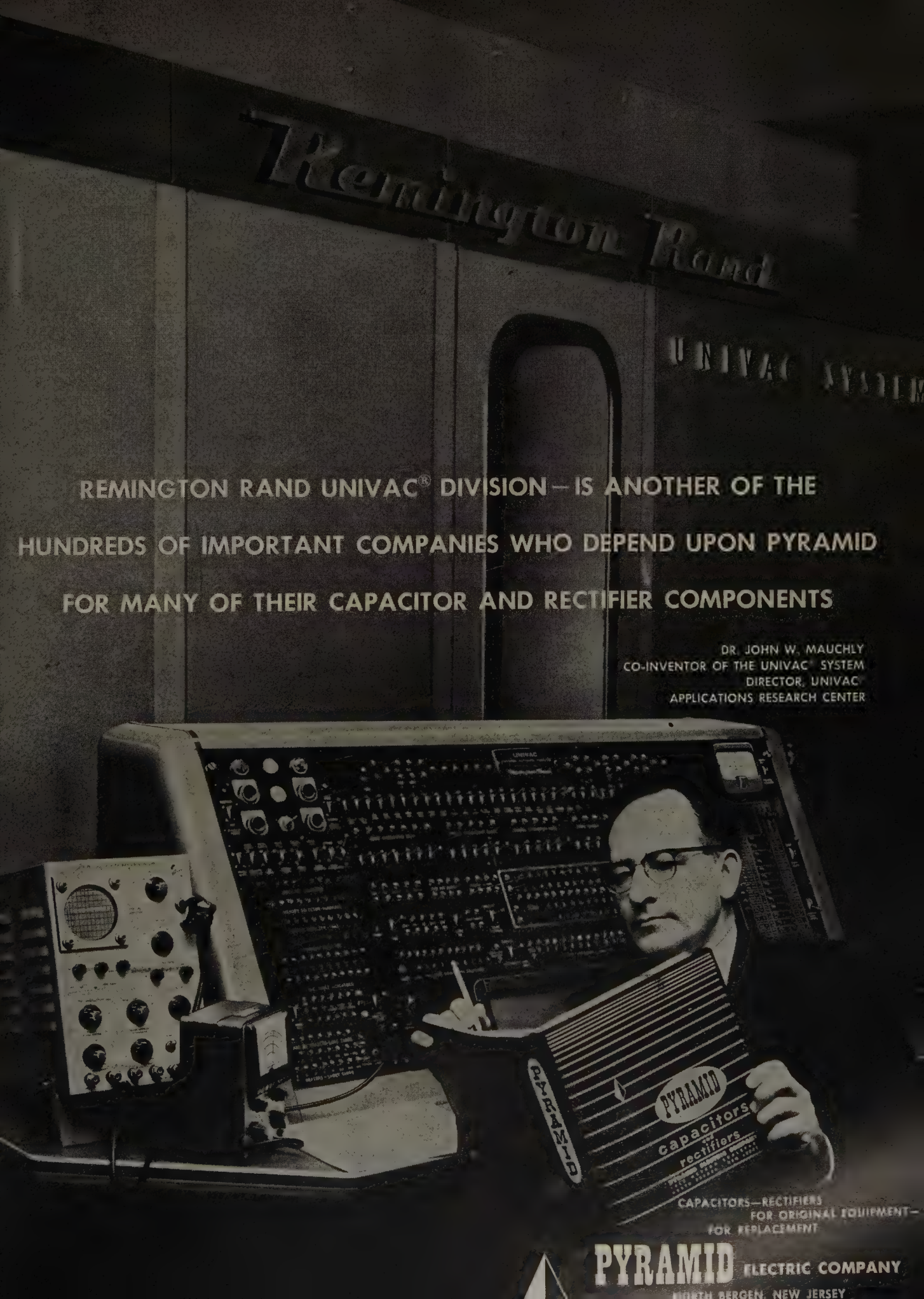
Elastic Stop Nut Corp. of America, Booth 2242.
See: AGA Division

Elco Corp., Booth 2234
"M" St. below Erie Ave.
Philadelphia 24, Pa.

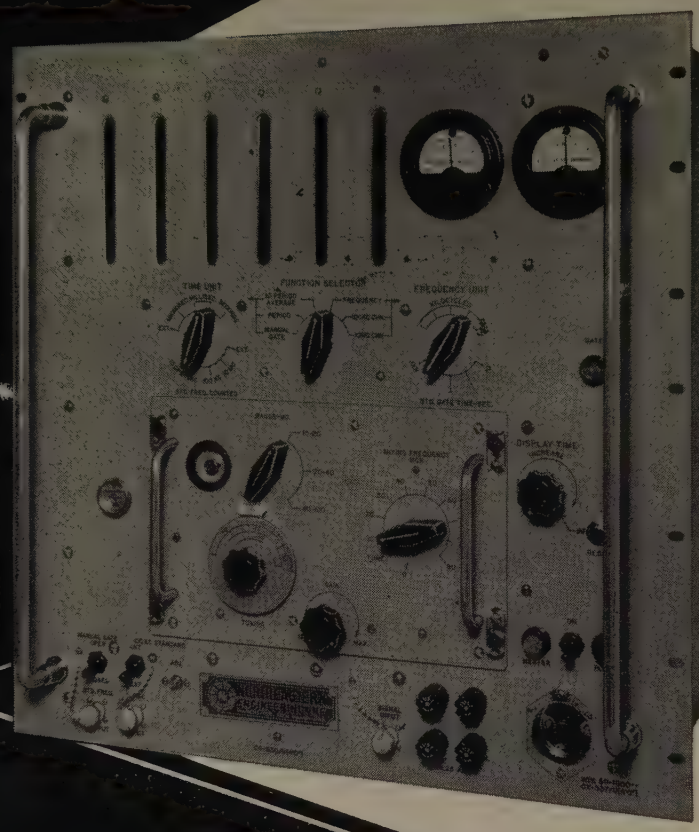
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(Continued on page 218A)


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electronic counter



CAT. NO. — NE — 14-20 FM

ACCURATE • SIMPLE
DIRECT READING
INSTANTANEOUS
RELIABLE

FREQUENCY MEASUREMENTS
10 CPS to 220 MC; TIME
INTERVAL 1 MS to 100 DAYS;
PULSE LENGTH, REP, RATES,
FREQUENCY DRIFT

northeastern engineering
Manchester New Hampshire

Whom and What to See at the Radio Engineering Show

(Continued from page 216A)

Elcor, Inc., Booth 3948
P.O. Box 354,
McLean, Va.

John Reeves

Regulated power supplies, pulse equipment.

Electomic Mechanisms, Inc.
P.O. Box 1156
Greenwich, Conn.
Booth 1615

Everett D. Hodge, R. J. McCarthy, Sidney Davis

The Electro-Mechanical Amplifier (EMA Servo) is a servo motor drive for automatic control systems that eliminates the requirements for a power amplifier. To be shown in the analytical system.

Electra Manufacturing Co.
4051 Broadway
Kansas City, Mo.
Booth 2338

R. I. Seymour, ▲R. A. Jarboe, ▲J. A. Thornton, R. R. Buron

A complete line of precision deposited carbon resistors for every requirement and Electra's miniature sealed switch. Introducing another Electra precision product the * "Ceramic Disc Capacitor."

Electric Eye Equipment Co., Booth 3033
Furst Electronics Division
1938 E. Fairchild
Danville, Ill.

C. M. Noble

Meters, amplifiers, and power supplies.

Electric Regulator Corp., Booth 2306
Pearl Street
Norwalk, Conn.

W. H. Walter

Transistor Magnetic Amplifiers, Under-Over Voltage & Frequency Controls, Static, Semi-Static, and Electro-Mechanical Voltage Regulators.

Electrical Industries
Div. Amperex Electronic Corp.
44 Summer Avenue,
Newark 4, N. J.
Booths 2526-2528

O. H. Brewster, Peter Muto, William Rauscher, ▲Karl Meyers, John Jonassen

New plant devoted exclusively to the production of glass-to-metal seals. Complete line of standardized sealed terminals, transistor closures, threaded seals and miniature closures.

Electrical and Physical Instrument Corp., Booth 3117
42-19 27th Street
Long Island City 1, New York

W. E. Hovemeyer, S. J. Lindenbaum, M. B. Gallant, M. C. Bugdons

*0-10 mc Nuclear Decade Scalers, Millimicrosecond rise Multi-Pulse Generators, *10 mc Wideband Amplifier, *Co-axial Mercury Switch Relay-Chopper, *Wideband Pulse Attenuator.

(Continued on page 222A)

* Indicates new product.

▲ Indicates IRE member.

ke it...



4CX300A
A remarkable general purpose power tetrode designed especially for compact, medium power equipment. Smaller than a tennis ball, it has a plate dissipation of 300 watts with forced air cooling and will operate to 500 megacycles at maximum ratings.

In recent years equipment manufacturers and users have been introduced by Eimac to a series of ceramic tube firsts unequalled in the industry: klystrons, negative grid tubes, rectifiers and receiving tubes.

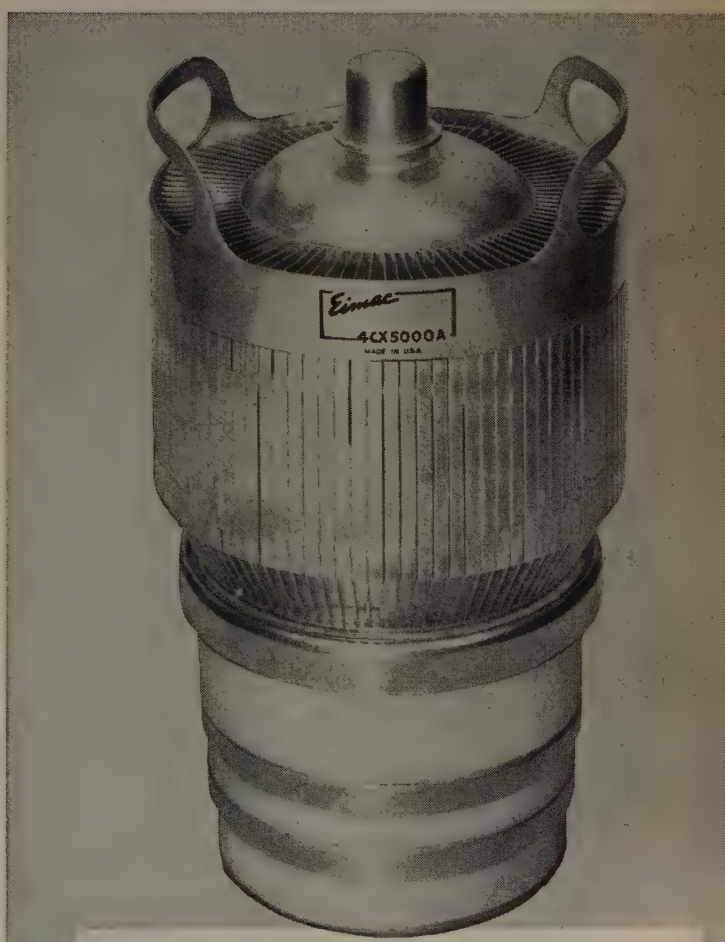
Clean, and rugged...these tubes can stand up to shocks and temperatures no glass tube can. Design and production advantages are a boon to equipment manufacturers and users alike.

As first in the field, Eimac has developed ceramic tube manufacturing techniques that have evolved into well established processes.

See this line of "tubes that can take it" at the Eimac exhibit, Booth 2410-12, National I. R. E. Show and Convention, March 18-21.

Eimac

EITEL-McCULLOUGH, INC.
SAN BRUNO · CALIFORNIA
The World's Largest Manufacturer of Transmitting Tubes



4CX5000A
This Eimac radial-beam power tetrode is especially suitable for single sideband operation. A rugged ceramic tetrode, it delivers 10 KW output in Class AB1 service and handles high inputs without going into the positive grid region.

WHY SPARK GAP TUBES ARE IMPORTANT–

and how Bendix Red Bank can help you with spark gap problems!



Bendix Red Bank "Spark Gap" Tubes are specially designed to do two big jobs in electronic circuits.

First, to act as a *"triggering" switch*—as on jet ignition systems. Here, Bendix* Spark Gaps pass high currents with relatively low voltage drop and have the advantage of being able to handle high voltages in small space. Further, these tubes can be made insensitive to ambient temperature variations and are not normally affected by pressure, altitude, or humidity changes.

The second function of Bendix Spark Gaps is as a *protective element*—guarding radar equipment against voltage overload, to name one example. Here, Bendix Spark Gaps keep high voltage surges from getting through to damage circuit components.

Our design and manufacturing experience with spark gap tubes is extremely broad. If our extensive line of these tubes . . . ranging from 750V to 50KV in DC breakdown voltages . . . does not already contain a type to fit your needs, we are in a position to design one to handle the job with the exact degree of efficiency that you require.

To find out more about what we can do to help you with your spark gap problems, get in touch with RED BANK DIVISION, BENDIX AVIATION CORPORATION, EATONTOWN, NEW JERSEY.

* TRADEMARK

West Coast Sales and Service:
117 E. Providencia Ave., Burbank, Calif.
Export Sales and Service:
Bendix International Division,
205 East 42nd St., New York 17, N. Y.
Canadian Affiliate:
Aviation Electric, Ltd., P. O. Box 6102,
Montreal, Quebec.

Red Bank DIVISION

Bendix AVIATION CORPORATION

Whom and What to See at the Radio Engineering Show

(Continued from page 218A)

Electro Devices Co., Inc., Booth 4107
580 Main St.
Wilmington, Mass.

A. Allyn Ryles, William Baker, Paul J. Post, Fred F. Cain, Richard Dacey, William Lees

New model semi-automatic miniature toroid coil winder capable of winding single, multi-stranded cotton covered and teflon wires, featuring power driven dereeler.

Electro-Flex Heat, Inc.
516 Asylum St., Hartford 5, Conn.
Booth 3841

Ronald J. Borrup, Harold C. Davis, Jr., Alex Fay, Tom Garrettson, Al Lospinoso, Walter Onyx



Heating Elements

Heating Elements, Electric, as Flexible as required from—90°F to 500°F, any shape, any size to 46" width. Silicone rubber insulation.

Electro Impulse Laboratory, Inc.
208 River St., Red Bank, N.J.
Booth 3316

I. Irving

Calorimeter, Power Meters, Direct Reading Calorimeter Bridge.

Electro Instruments, Inc., Booth 3614
3794 Rosecrans St.
San Diego 10, Calif.

Walter H. East, Bud Edelman, Rolland Flemons, Peter De Witt, John Sadler

Transistorized modular digital instruments for DC, AC, Ratios. Complete modular data handling systems. X-Y Recorders and accesories.

Electro-Measurements, Inc.
7524 S.W. Macadam Ave.
Portland 1, Oregon
Booth 3010

▲ Mr. Doug Strain, ▲ Mr. Lawrie Rockwood, ▲ Dr. Merle Morgan, ▲ Mr. Larry Morgan



General purpose impedance bridge

* Precision Rack Mounted LRC General Purpose Impedance Bridge designed for Audio Frequency Operation. Also, Capacitance Bridges; and Decade voltage Divider, Resistor, and Capacitor Components.

(Continued on page 224A)



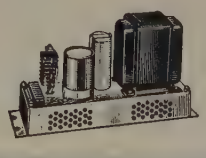
CONVENIENT CARRYING HANDLES *are available as an accessory with the new adjustable Sola regulated dc power supply. Here they are in use by an engineer as he lifts the DC Solavolt onto test bench.*

You can "dial" lab test voltages for high-amp loads with this compact, regulated DC power supply

Looking for an *adjustable* source of regulated dc test voltages for design development? Investigate the new Sola Constant Voltage DC Power Supply — the *"DC Solavolt"*. Six models — each with a different output range —span the entire region between 5 volts at 7 amperes, and 400 volts at 0.6 amperes. Each delivers laboratory standards of performance — output voltage regulated within ±1% though input voltage varies ±10%; ripple voltage held within 0.10%, rms.

Design simplicity of the *DC Solavolt* offers compact size, low weight, high efficiency, high short-time overload capacity, and moderate price. All stock models occupy only 7" of height and 12¼" of depth on a standard 19" relay rack frame. There are no tubes to replace, no "compensating" adjustments are needed, and no maintenance is required. Carrying handles, available as accessory equipment, provide "one-man portability" and self-stacking. Your local electronic distributor, who stocks the *DC Solavolt*, will be happy to give you further information, or visit IRE Show Booths 2817-19.

SOLA *Constant Voltage* **DC POWER SUPPLIES**



WRITE FOR TECHNICAL BULLETIN 1C-DC-245
SOLA ELECTRIC CO.
4633 W. 16th Street
Chicago 50, Illinois

CONSTANT VOLTAGE TRANSFORMERS • FLUORESCENT LIGHTING BALLASTS • MERCURY VAPOR LIGHTING TRANSFORMERS
SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414 • *NEW YORK 35: 103 E. 125th St., TRafalgar 6-6464 PHILADELPHIA: Commercial Trust Bldg., Rittenhouse 6-4988 • BOSTON: 272 Centre Street, Newton 58, Mass., Bigelow 4-3354 • CLEVELAND 15: 1836 Euclid Ave., PRospect 1-6400 • KANSAS CITY 2, MO.: 406 W. 34th St., Jefferson 4382 • LOS ANGELES 23: 3138 E. Olympic Blvd., ANgelus 9-9431 • SOLA ELECTRIC (CANADA) LTD., TORONTO 17, ONTARIO: 102 Laird Drive, Mayfair 4554 • Representatives in Other Principal Cities*

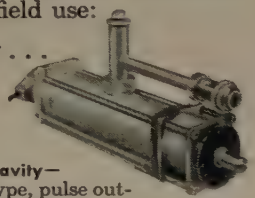
NOW...ANY MICROWAVE COMPONENT CAN BE BUILT AND ENGINEERED TO YOUR PARTICULAR APPLICATION

Regardless of complexity, design or tolerance problems—you can get UHF or microwave components that are job-engineered to your application. All units are delivered, *electrically tested and proven*, ready for immediate operation.

Components can be built from your prints or can be designed and built to integrate with the application. Close and confidential coordination is maintained from drawing board stage to installation.

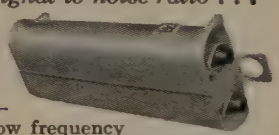
Range of assemblies is practically unlimited—from dc. to over 40,000 mc., military or industrial. Typical examples are these components, delivered ready for field use:

Telemetering . . .



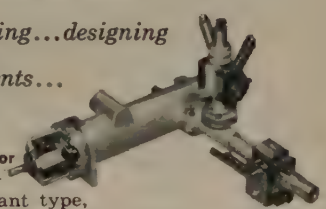
Tuneable S-Band Transmitter Cavity—re-entrant type, pulse output 150 w., operates at extreme altitudes and under extreme conditions of temperature, humidity and salt spray.

Improving signal-to-noise ratio . . . selectivity...



Tuneable UHF Pre-Selector—relatively low frequency coaxial resonator with very low insertion loss, extreme selectivity and very high signal-to-noise ratio. Especially adapted to use in aircraft or in crowded communication bands.

Calibrating...designing S-Band components...



S-Band Signal Generator Cavity—re-entrant type, complete with thermistor mount and calibrated variable attenuator. Frequency range 2700 to 3400 mc.

•

CUSTOM-ENGINEERED MICROWAVE PARTS

Get the facts on our complete design, engineering and mechanical fabrication facilities. Have us quote on your needs—cavities, mixers, duplexers, multipliers, rotary joints, twists, bends and other components or assemblies.

Contact us today. Request catalog.

J-V-M J-V-M ENGINEERING COMPANY

4632 LAWNDALE AVENUE, LYONS, ILLINOIS
(Chicago Suburb)

Whom and What to See at the Radio Engineering Show

(Continued from page 222A)

Electro-Mec Laboratory, Inc.
47-51 33rd Street
Long Island City 1, N. Y.
Booth 2713

Robert Wiener George A. Jackson, Phil Luce, ▲ George Boziwick, Larry G. White, Austin Schweitzer, Dixon Teter

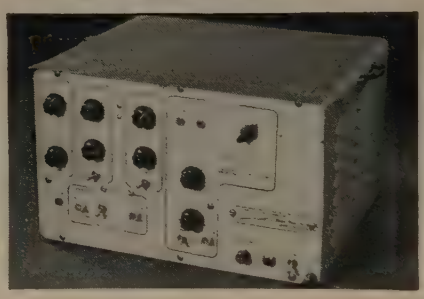


Goniometer—shaft positioner

"GONIOMETER," A NEW CONCEPT IN A PRECISION (±1 minute) shaft positioner. For engineers, inspectors, and technicians to evaluate, test and calibrate potentiometers, synchros and shaft encoders.

Electro-Pulse, Inc.
11861 Teale, St.
Culver City, Calif.
Booths 3611-3613

J. E. Neibuhr, ▲ Dr. Norman H. Enenstein, Robert J. Johnson.



Model 2125A Pulse Generator

Electronic Counters, Pulse Generators, * Time Interval & Frequency Meters, * Preset Counters, Totalizers, * Print-Out Counters, * Digital Volt Meter Pulse Generators, Magnetic Core Testers, Delayed Trigger Generators and Pulse Voltage Calibrator.

Electro-Snap Switch & Mfg. Co., Booth 2225
4218-30 West Lake Street
Chicago 24, Illinois

H. F. Ames, G. M. Ballee, H. I. Anderson, E. C. Connelly

An exclusive "Push-Push" or "Double Action" switch (Push once and circuit is made: Push again and circuit is broken). Soon available in standard circuit arrangements from S.P.S.T.-N. O. to T.P.D.T.-6 circuits. Ratings 10 AMPS, 125VAC, 10AMPS, 30VDC.

Electro Tec Corp.
10 Romanelli Ave.,
S. Hackensack, N. J.
Booth 1216-1220

R. E. Shumate, James J. DePalma, G. W. Thacker, L. P. DeSimone, E. C. Clarke, R. J. Schmitt

The Mark II Relay, new and revolutionary design Slip Ring, Commutators and Brush Assemblies, individual components and completely housed assemblies. Miniature switches and related products.

(Continued on page 226A)

Designed For Development



PRECISION BREADBOARD KITS *by PIC*

For INDUSTRY — SCHOOL — LABORATORIES — MILITARY ENGINEERING or DEVELOPMENT CONTRACTS

Practical, low cost kits of standardized precision instrument components for rapid assembly of mechanical breadboards and servo control systems.

NINE MODELS NOW AVAILABLE—
1/8" — 3/16" — 1/4" SHAFT SIZES

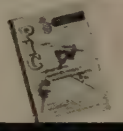
Master kits contain over 650 precision parts and components, including

Base Plates • Gears • Shafts • Hangers • Bearings • Differentials • Couplings • Limit Stops, etc.

All contained in sturdy, compartmented, leather carrying case, complete with assembly tools.

Basic kits may be expanded at any time, by addition of STOCK parts and components listed in the new, 128-page PIC Catalog #11.

WRITE TODAY for further information, parts lists and prices.



NEW CATALOG AVAILABLE!
128 Pages of standardized Precision Parts and Components available for IMMEDIATE DELIVERY from STOCK . . . Over 250 items, with detailed specifications and prices.

SEND FOR YOUR COPY NOW.

PIC design corp.
Div. of BENRUS WATCH CO., INC.
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all the possibilities of designing for compactness, simplicity, and increased sensitivity?

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THERMISTORS & VARISTORS

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Manufacturers of
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VARISTORS
GAS ANALYSIS CELLS

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Tel. MUrdock 8-7150

VISIT VICTORY AT THE IRE SHOW

NIXIE ELECTRONIC INDICATING TUBE

SEEING IS BELIEVING

WIDE VIEWING ANGLE

PERFECTLY FORMED NUMBERS — PRECISELY ALIGNED

ELECTRONIC — NO TORQUE LIMITATIONS

CONTROLLABLE BRILLIANCE

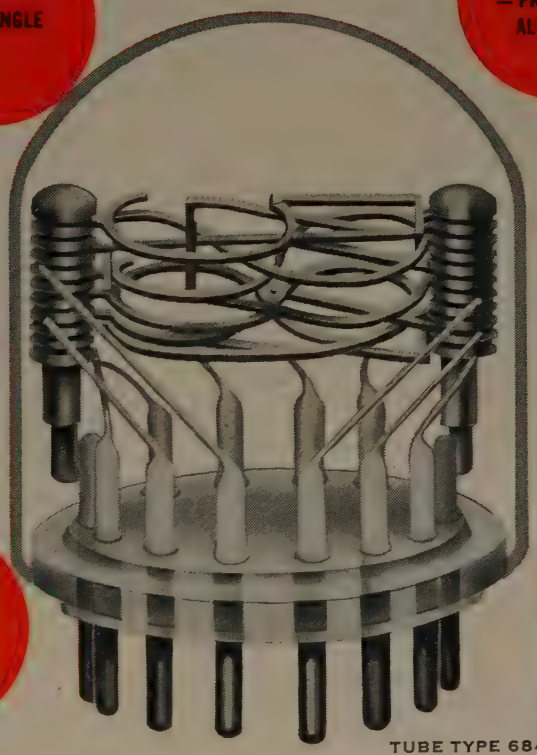
RUGGED CONSTRUCTION

LONG LIFE

MINIMUM VOLUME FOR GIVEN NUMBER SIZE

SIMPLE PLUG-IN STEM HIDDEN TUBULATIONS

SIZE 1" x 1"



TUBE TYPE 6844

SOME TYPICAL NIXIE APPLICATIONS

1. INDUSTRIAL CONTROL
2. INSTRUMENTATION
3. COUNTERS
4. COMPUTERS
5. MILITARY ELECTRONIC INDICATORS
6. CHANNEL INDICATOR
7. INDICATOR BOARDS
8. DIGITAL VOLTMETERS
9. PAGING SYSTEMS
10. ELEVATORS
11. RADAR

Be sure to see us at Booths 1720-22-24.

ANY NUMBER SELECTED IS INSTANTLY READABLE

The first mass-produced all electronic readout tube . . . **NIXIE IS NOW IN VOLUME PRODUCTION** at the Burroughs Corporation Electronic Tube Division . . .

NIXIE is a gas-filled, cold cathode tube which contains all the numerical digits 0 to 9, any individual number can be simply selected and displayed in a common viewing area, the ideal method for converting electro-mechanical or electronic signals directly to readable characters.

NIXIE Design Advantages include: Unlimited Rate of Change. Lowest cost in-line Indicator. Lowest Power in-line Indicator. Operation Unaffected by Temperature Changes. Multiple Remote Indications From One Driving Circuit. Production Uniformity From Tube to Tube and Number to Number. Human Engineered for Performance, Appearance, and Reliability.



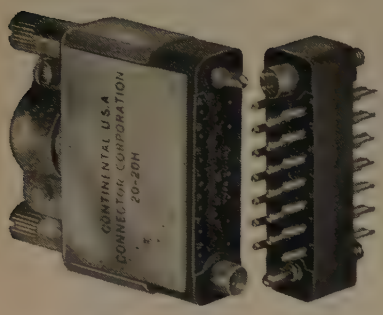
Electronic Tube Division

BURROUGHS CORPORATION

Plainfield, New Jersey

new!... Continental Connectors

Series '18' connectors with polarizing screwlocks*



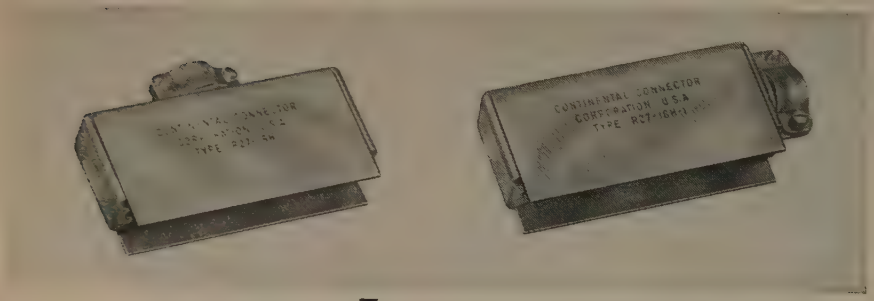


POLARIZING SCREWLOCKS
*PAT. NO 2746022

The new Series '18' provides a large, rugged contact with the same efficient spacing used on our Series '20'. The .053" diameter solder cups can accommodate two #20 AWG wires, if necessary. 20, 27 and 50 contact units are available.

Our reverse type guide pin and guide socket arrangement provides positive polarization. To insure against accidental disconnection you can order the Series '18' with the exclusive Continental Polarizing Screwlock.

Anodized aluminum hoods with top or side openings are available for positive cable support and strain relief.



GUIDE PIN and GUIDE SOCKETS



SERIES '18' SPECIFICATIONS

CONTACTS: 20, 27 and 50—plus other contacts and arrangements (9, 14, 34 will be available soon).

Contact pins (brass) and sockets (spring temper phosphor bronze) are silver and gold plated for low contact resistance.

TERMINALS: Solder cup or turret.

ELECTRICAL RATINGS:

Voltage Breakdown	
At Sea Level	2100 Volts RMS
At 60,000 Ft.	750 Volts RMS
Current Rating	5 Amps

Additional information on these connectors, and special designs requiring the use of subminiature, printed circuit, hermetic seal, pressurized, high voltage, or power connectors are available on request. Write today for free catalog.

you're sure with

Booth 3911-13 IRE Show

DeJUR

ELECTRONIC SALES DIVISION
DeJUR-Amsco Corporation
45-01 Northern Blvd.
Long Island City 1, N. Y.

Whom and What to See at the Radio Engineering Show

(Continued from page 224A)

Electro-Voice, Inc., Booth 1317
Buchanan, Mich.
Howard Durbin, James Johnson
Professional Microphones, Public Address Microphones, Communications, Microphones, Ceramic Cartridges, Public Address Speakers and Horns.

Electronic Advertiser, Booth 4056
1110 F St., N.W.
Washington 4, D.C.
Bill West
Latest issue of *Electronic Advertiser* announcing the "Electronize Our Highways" contest—details given in booth.

Electronic Applications, Booth 3002
392 State St.
Meriden, Connecticut
V. J. Skee
"REVOX" Tape Recorders and Phonograph Turntable assembly. "EMT" Professional Transcription Turntable and Instruments. "Nagra" Portable self-powered professional Tape Recorders. "Schomandl" Precision Frequency Decade Measuring Units. "Klar & Beilschmidt" Specialized ceramic turret hardware. "Metrawatt" High Voltage, portable, Insulation Testers. "Gotham Audio Development."

Electronic Associates, Inc.
Long Branch Ave.,
Long Branch, N. J.
Booths 1202-1208
▲ C. Marsh, ▲ J. Kennedy, R. Yeager, J. McCloskey, J. Strong, C. Worley, N. Seiler, B. Johnson, C. O'Hara
Precision Analog Computing Systems (PACE) and associated output recording equipments. *Superior components with vastly improved performance chaarcteristics and new applications. *Packaging system which facilitates immediate expansion. *Programming system which employs digital techniques—known as ADIOS.

Electronic Devices, Inc., Booth 2934
429 12th Street
Brooklyn 15, New York
▲ Irwin Weitman, Henry S. Ovrut, Jose Velez
Midget toroid coil winder, winding toroids.

Electronic Equipment, Booth 4028
172 South Broadway
White Plains, N. Y.
Glenn Sutton, R. A. Neubauer, Glenn Sutton, Jr., Edw. Sutton, ▲ Ronald K. Jurgen, ▲ Roland Higgins, ▲ Kenneth Stone, John Iracci, Leonard C. Davis, John Lupton, David Phillips, Harry O. Andrews, A. Jay Davis, Nat C. Berro
The magazine of design and manufacture providing complete coverage of the entire Electronic Original Equipment Manufacturing Market with over 28,000 design, development, and research engineers.

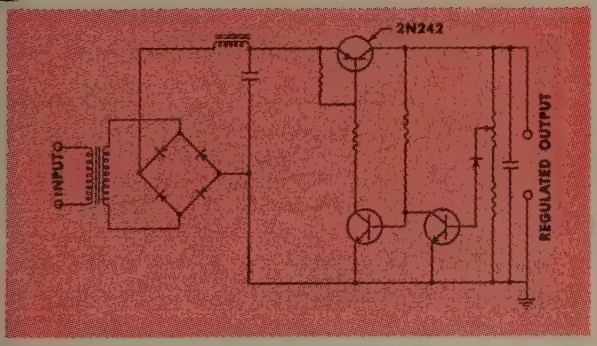
Electronic Fabricators Inc.
682 Broadway
New York 12, N. Y.
Booth 3933
▲ M. Samuels, G. Gallwey, R. Couppez, ▲ J. Codina
New at EFCON . . . plug in capacitors for printed circuitry . . . featuring our standard close tolerance and high reliability . . . all sizes and styles . . . designed to your specifications.

(Continued on page 230A)

* Indicates new product.
▲ Indicates IRE member.



Here are just some of the applications in which designers are effectively using or planning to use the 2N242



***Transistor Voltage Regulation**

Transistorization of voltage regulator circuits is one of the most popular general purpose applications indicated for the 2N242. Here is a typical regulator circuit incorporating the Type 2N242. DC to AC converter rates second in popular usage for this power transistor.

How about your general purpose plans for the Type 2N242 power transistor? Call your Sylvania representative or write for technical data.

- *** VOLTAGE REGULATION**
- **DC CONVERTER**
- **OSCILLATOR, AMPLIFIER**
- **TRANSISTOR COMPUTER**
- **MAGNETIC CORE DRIVER**
- **SERVO AMPLIFIER**
- **VERTICAL SWEEP OUTPUT**
- **PULSE POWER OUTPUT**
- **HIGH CURRENT SWITCH**
- **RF MODULATOR**

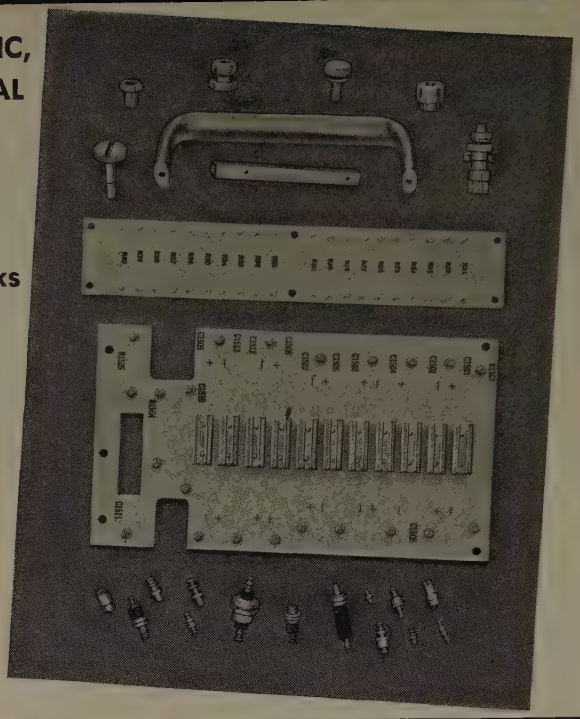
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PARTS for ELECTRONIC, ELECTRO-MECHANICAL and AIRCRAFT-STANDARD or to SPECIFICATION

- Dial and Shaft Locks
- Standard Terminal Lugs
- Terminal Boards
- Handles

Immediate delivery from stock or to order on all items.

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GCI

GENERAL COMPONENTS, INC.
225 EAST 144th STREET, NEW YORK 51, N. Y.
Telephone: MO 5-0740

Grid-Controlled Indicator Tube Monitors Transistor Circuits



KP-125, Actual Size

The KP-125 is a subminiature, grid-controlled indicator tube which operates with small signal voltages and negligible current. A gas-filled triode of the glow-discharge type, the KP-125 provides a visual glow which may be viewed end-on or from the side. Both the filament (very low drain hearing aid type) and the anode may be operated from the AC line and consume power in the milliwatts region. The tube glows with 0 volts on the grid and extinguishes with −3 volts on the grid. Flying leads are provided for direct soldering into circuits, such as on printed boards. The characteristics of the KP-125 make it useful in computer transistor circuits as an indicator of current conditions which does not load the circuit under test. Additionally it serves as an indicator for monitor service in remote control panels. *For details on this and other special purpose electron tubes, write:*

KIP ELECTRONICS CORPORATION

Dept. MP, Stamford, Connecticut

Whom and What to See at the Radio Engineering Show

(Continued from page 226A)

Electronic Industries & TeleTech, Booth 4303
Chestnut & 56th Sts.
Philadelphia 39, Pa.

Blair McClenachan, Bernard Osbahr, ▲ William D. McCarney, Joseph Drucker, Gerald B. Pellissier, Menard Doswell, III.

*1957 Electronic Spectrum Chart. The only one of its kind offered to electronic engineers—an exclusive feature found only in ELECTRONIC INDUSTRIES. "40,500 circulation." It serves an engineering readership concerned with the design, production and manufacture and operation of consumer and industrial electronic devices and equipment.

Electronic Instrument Co., Inc., Booth 3407
84 Withers St.
Brooklyn 11, N. Y.

Harry R. Ashley, Philip A. Portnoy, Mel Fink, Richard Dugot, Robert Clark-Duff

Electronic test equipment and high fidelity—Kit or factory wired. VTVM's, Oscilloscopes, Tube Testers, Generators, VOM'S, Signal Tracers, Decade Boxes, Battery Eliminators, Amplifiers.

Electronic Measurements Co., Inc.
Lewis St. and Maple Ave.
Eatontown, N. J.
Booths 3042-3043

B. De Blasio, J. W. Raczek

Programmable power packs. Extensively used in tube, transistor testers and computers. Regatron® and transistor voltage or current regulated power supplies; calibrators; ac line regulators.

Electronic Mechanics, Inc., Booth 4239
101 Clifton Blvd.
Clifton, N.J.

D. E. Replogle, Bryce Replogle, Nathan E. Brown, J. E. Nester, Ken Ivy, Seymour Vanowski, Dr. Brandenburg, Viekko Houtario, Don Nies, Dick Sachleben, Don Spencer, Bill Frey

Synthetic glass bonded mica—MYKROY

Electronic Periodicals, Inc., Booth 4406
2775 So. Moreland Blvd.
Cleveland 20, Ohio

Robert A. Harris

Publications: Radio & Electronic Jobber News, Source Guide for Components & Equipment. 1957 Edition "Who's Who in Electronics." Military Electronics.

Electronic Research Assoc., Inc.
67 E. Centre Street
Nutley 10, New Jersey
Booth 2705

▲ D. D. Grieg, ▲ N. T. Gottfried, ▲ S. Moskowitz, ▲ M. Perry

* Adjustable Transistorized Transpacs, * Semi-Conductor Inverters-Converters, * High Current Transistorized Power Supplies, TRANSPAC Miniaturized Transistor Power Packs, Transamp packaged Transistor Circuits, Tubeless Power Supplies, Transistor Test Equipment. TRANSPAC Semi-Conductor Inverters/Converters.

(Continued on page 232A)

Complete product information Booth 1113—first floor

Another *NEW* Plug-In Unit

to *increase* the value of your Tektronix Type 541 and Type 545 Oscilloscopes



High Sensitivity for Fast-Rise Applications—The new Type 53/54L Fast-Rise High-Gain Preamplifier plugs into your Type 541 and Type 545 Oscilloscopes, increasing the calibrated vertical deflection factor to 5 millivolts/cm. At the higher deflection factors (5 millivolts/cm to 50 millivolts/cm), risetime is 0.015 μsec and vertical passband is 3 cycles to 24 mc. From 50 millivolts/cm to 50 volts/cm characteristics are the same as the Type 53/54K Unit... risetime 0.012 μsec, passband dc to 30 mc. Input capacitance is 20 $\mu\mu$f direct, 8 $\mu\mu$f with the 10x attenuator probe furnished with Type 541 and Type 545 Oscilloscopes. Other probes with higher attenuation ratios are available to reduce input capacitance to as little as 2.5 $\mu\mu$f.

Type 53/54L Fast-Rise High-Gain Unit.....$185

First shipments are expected to be made during July, 1957. Please keep in touch with your Tektronix Field Engineer or Representative for current details.

OTHER PLUG-IN UNITS FOR TYPE 530-SERIES and TYPE 540-SERIES OSCILLOSCOPES

Type 53/54A—Wide-Band DC Unit .....$ 85
Type 53/54B—Wide-Band High-Gain Unit ... 125
Type 53/54C—Fast-Rise Dual-Trace DC Unit .. 275
Type 53/54D—Differential High-Gain DC Unit 145
Type 53/54E—Low-Level Differential AC Unit 165
Type 53/54G—Differential Wide-Band DC Unit 175
Type 53/54K—Fast-Rise DC Unit 125

Prices f.o.b. Portland, Oregon

SEE THE TYPE 53/54L UNIT AND OTHER NEW TEKTRONIX INSTRUMENTS AT THE IRE SHOW, BOOTHS 3028, 3029 AND 3030.

Tektronix, Inc.

P. O. Box 831 • Portland 7, Oregon
Phone CYpress 2-2611 • TWX-PD 265 • Cable: TEKTRONIX

The Vacuum Switch Goes to Work IN HIGH VOLTAGE DC CIRCUITS

Jennings RADIO
VACUUM ELECTRONIC COMPONENTS

Years of experimentation and commercial usage have demonstrated that Jennings vacuum switches can interrupt many dc circuits that cannot be easily handled in any other way. They can "make" the high inrush currents that occur when capacitor banks are discharged and they can interrupt the fault currents that occur during the flashover of a power tube in a transmitter.

DC power supplies are now being switched "hot" from low power levels up to 250 kw under either normal or overload conditions. Overcurrent protection is excellent since operate times are only 4 to 10 milliseconds and deionization of the arc is extremely rapid in a high vacuum. Likewise, high voltage isolation, capacitor discharge, or safety grounding is easily accomplished with contact travels of no more than 1/8" regardless of voltage level. This makes possible solenoid actuating mechanisms that are simple in design and lend themselves to completely automatic operation.

Please send us your circuit conditions. We can suggest vacuum switches that will solve most difficult dc switching problems.



TYPE RH7 85 kv N/C Grounding Relay



TYPE RH1G N/O for dc interruption up to 200 kw



TYPE R8G Overload Circuit Breaker



TYPE R1G N/O with 40 kv insulation

JENNINGS RADIO MANUFACTURING CORPORATION · 970 McLAUGHLIN AVE.
P.O. BOX 1278 · SAN JOSE 8, CALIFORNIA

Whom and What to See at the Radio Engineering Show

(Continued from page 230A)

Electronic Specialty Co.
5121 San Fernando Road
West Los Angeles 39, Calif.
Booth 3009

Herbert S. Woodward, C. Ray Harmon, Ted Duay, William P. Stratton, Roy E. Brady, Colin J. Campbell

4 PDT, 2, 5, and 10 ampere Subminiature Relays. Transistorized Time Delay, Over and Under Frequency and Voltage Relays. VHF Blade and Slot Antennas, Diplexers, Coax Switches, Custom Electronic and RF Components.

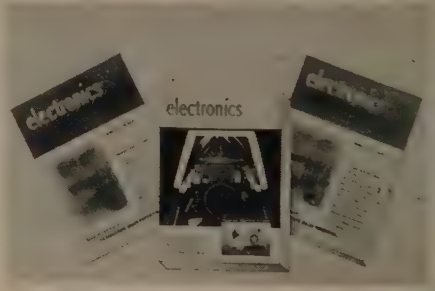
Electronic Tube Corp., Booths 3112-3113
1200 East Mermaid Lane
Chestnut Hill
Philadelphia 18, Pa.

▲ K. Meinken, Sr., ▲ K. Meinken, Jr., ▲ R. Brunner, ▲ R. Rude, ▲ W. Hill

*High-frequency, 15 megacycle Dual-Channel Oscilloscope Model H-42B; Recording Cameras—Continuous Strip and Drum Types; Automatic Process Film Developer; Multi-Gun Cathode Ray Tubes for industrial and military applications. Complete line of single and multigun tubes for radar and instrumentation.

Electronics-Nucleonics
330 West 42 Street
New York 36, N. Y.
Booth 4308

James Girdwood, Donald H. Miller, James T. Hauptli, Henry M. Shaw, Martin J. Gallay, Wm. S. Hodgkinson, Bruce Winner, Walter M. Luce, Warren H. Gardner, Carl W. Dysinger, William Smith



ELECTRONICS Technical Edition, published the 1st of each month; 2 Business Editions, published the 10th and 20th of each month; plus the mid-year ELECTRONICS BUYERS' GUIDE feature 3 panels of pipe-and-clamp display. 4th panel covers NUCLEONICS 10th anniversary and NUCLEONICS BUYERS' GUIDE.

See McGraw-Hill Publishing Co., Inc.

Electronics Plastic Corp., Booth 2130
675 Barbey Street
Brooklyn 7, N. Y.

See: Eastern Precision Resistor Corp.

Elgin Metalformers Corp., Booth 1825
901-907 No. Liberty Street
Elgin, Illinois

J. G. Wells, S. K. Frankel, H. Golz, L. Fay

New corner compartment units and new heavy duty rack cabinets featuring the EMCOR Modular Enclosure System Display.

Elgin National Watch Co., Electronic Div., Booth 2426
2435 N. Naomi St.
Burbank, Calif.

E. C. Carlson, Frank S. Schaumburg, ▲ Eric Firth, Fred Winter, ▲ Glen Soper, Bill Sheffield

To solve your high shock-rough vibration and limited space problems—Elgin presents the VG and MV series of subminiature relays.

(Continued on page 235A)

Whom and What to See at the Radio Engineering Show

(Continued from page 232A)

Emerson & Cuming, Inc., Booth 4404
869 Washington Street
Canton, Mass.

▲ W. R. Cuming, J. Copley, G. Niles, R. Stetson.

Plastics for Electronics Microwave Absorbers; Casting Resins; Foams; Ecco Reflector; Adhesives; Impregnants; Dielectrics; Materials for use to 1200°F.

Emerson Plastics Corporation
Seabury Avenue and Butler Place
Bronx 61, N. Y.
Booth 4523

W. Eisfelder, A. Margosian, S. C. Kirstel



Precision fabrication of all plastics materials—machining, deep-drawing, vacuum-forming, metal components, marking, assembly.

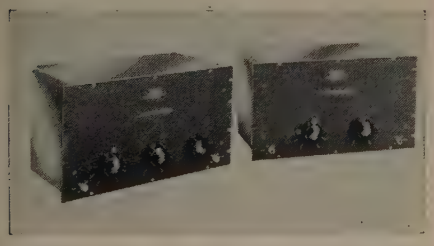
Emerson Radio & Phonograph Corp., Booth 1427
14th & Coles Street
Jersey City 2, New Jersey

W. L. Dunn

Magnetic amplifiers, analog computers, communications equipment.

Empire Devices Products Corp.
38-15 Bell Blvd., Bayside 61, New York
Booths 3818-3820

M. T. Harges



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Noise meter, generators, attenuators, power supply.

Endevco Corp., Booth 3036
161 East California St.
Pasadena, Calif.

▲ H. Dudley Wright, ▲ Wilson Bradley, Jr.

A * 500°F. Piezoelectric accelerometer is featured with systems for indicating, recording, and telemetering dynamic acceleration, pressure and force over wide amplitude and frequency ranges.

Enflo Corporation, Booth 4027
Route 38 at Airport Circle
Pensauken, New Jersey

▲ Merritt A. Rudner, Richard A. Boulden, J. N. Barrett, George Stech

Engineered Fluorocarbons; Teflon Sheet, Rod, Tubing, Pressure Sensitive Tape, Cementable Tape, Feed-Through and Stand-Off Insulators, and Teflon Mixtures.

(Continued on page 236A)

Installed World-Wide for Greater Wiring Dependability

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Plasticote Multiple Conductor Cable — multiple conductors (No. 16 AWG to No. 26 AWG) bare or tinned, solid or stranded annealed copper are available.

Plasticote Miniature Wire and Cable — single or multiple conductors bare or tinned, solid or stranded copper with thin wall Plasticote insulation.

Plasticote Hook-up Wire — made to conform to the requirements of Specification JAN-C-76 and MIL-W-76A in solid or stranded constructions.

Plasticote Coaxial Cable—(RG/U) to conform to JAN-C-17A and MIL-C-17B requirements are available. Special designs of coaxial cable transmission lines available.

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Easier Working... Super Durable!

Chester Plasticote is the rugged insulation that adds years to wiring life. Super-durable, Plasticote also offers the smooth pliable qualities that make Chester conductors easier to work with. Specifying Plasticote means you raise wiring quality at the same time you increase wiring production! Call or write for wire samples and bulletins.

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A Subsidiary of Miami Copper Company

Transistor Evaluation
at a glance



TRANSISTOR CURVE TRACER

- EIGHT-CURVE FAMILY PRESENTATION
- TESTS PNP-NPN TRANSISTORS
- COMPARES TRANSISTOR CHARACTERISTICS
- INDICATES BI_{co}, B, AND r_c

FULLY TRANSISTORIZED • SELF-POWERED • PORTABLE
(Weighs only five pounds)

The 504's dynamic display of eight output characteristics for grounded emitter connection provides immediate visual satisfaction for 95% of all low power transistor needs. Used for circuit design, production test, and receiving inspection applications, complete performance indication is given on any oscilloscope without disturbing flicker allowing instantaneous rejection of malfunctioning transistors.

CUBIC CORPORATION

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Whom and What to See at the Radio Engineering Show

(Continued from page 235A)

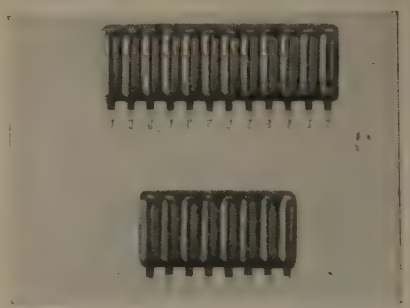
Engelhard Industries, Booths 2102-2106
113 Astor Street
Newark 5, New Jersey
See: D. E. Makepeace and Baker & Company, Inc.

Epco Products, Inc., Booth 2243
2500 Atlantic Ave.
Brooklyn 7, N.Y.
E. Mullin
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Epsco Inc., Booths 1818-1820
588 Commonwealth Ave.
Boston 15, Mass.
▲ A. Munzig, Jr., B. Gordon, J. Davis, ▲ I. Stone, W. Peet, ▲ F. Young, D. Casale, L. M. Briant
Automatic data processing and control components, equipment and systems—DATRAC (analog-to-Digital converter), Secondary, Standard Voltage Reference Source, Delay Lines, Shift Registers, Pulse Transformers, MAGNELINE (visual read-out indicator).

Ericsson Corp., Booth 3935
(Telefonaktiebolaget)
100 Park Ave.
New York 17, N. Y.
Ake Ehnborg
Electron tubes.

Erie Resistor Corp.
644 West 12th Street, Erie, Pa.
Booth 2515
▲ J. D. Heibel, ▲ J. C. VanArsdell, A. K. Shenk, W. R. Crotty, D. N. Sawtille, M. E. Darrin, ▲ F. Rich, P. Sterner, ▲ J. Foster, ▲ Willaim L. Klevans, R. A. Elliot, ▲ Richard H. Anderson



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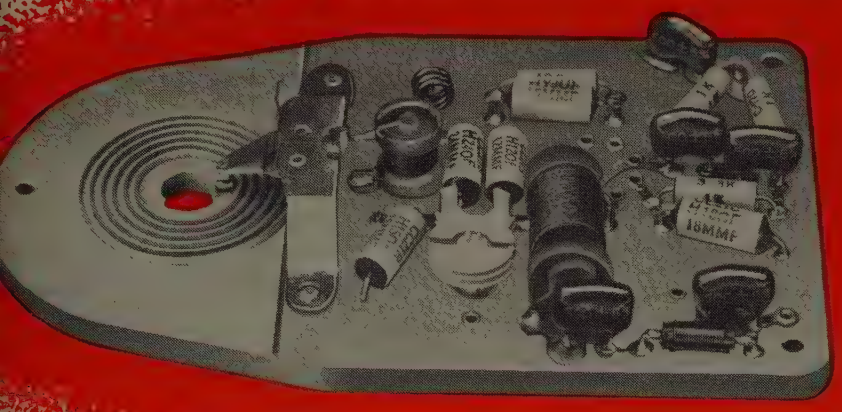
Essex Wire Corporation, R-B-M Division, Booth 2525
1601 Wall Street
Fort Wayne 6, Indiana
V. A. Hedlund, P. C. Talmadge, W. T. Hopkins, H. Jules, J. B. Campbell, H. Lee.
Open and Hermetically Sealed * Relays, Radio Sonde Relays*, AC Industrial Contactors*, Antenna Switching Relays and Power Type Relays.*

Eugene Engineering Co., Inc., Booth 4603
1217 Hyde Park Ave.
Boston 36, Mass.
Albin Baranowski, Russell Blank, Edmund H. Race, Joseph E. Eifler
Magnesium Fabrication, Electronic Panel, Chassis, Frames, Cases.

(Continued on page 238A)

* Indicates new product.
▲ Indicates IRE member.

design achievements with SUPRAMICA* ceramoplastics



CIRCUIT WITH SUPRAMICA 555 CERAMOPLASTIC BASE



SIGNAL CORPS' VEHICULAR RECEIVER R-745 ( )/VRC

SUPRAMICA* 555
ceramoplastic insulation
increases stability of new AVCO STABLE OSCILLATOR

Ceramoplastic's dimensional stability maintains frequency under extreme conditions to ±6 kc at 40 mc without crystals . . . doubles channel capacity.

In one version of the Signal Corps' New Vehicular Receiver R-745 ( )/VRC is an advanced tuning unit that eliminates the requirement for many conventional crystals and their accompanying spurious heterodyning problems. Designed for "automated" assembly by the AVCO Manufacturing Corporation, Crosley Division, this extremely stable tuner utilizes a unique continuously tunable oscillator circuit, consisting of silver ribbon, precision-molded in a base of SUPRAMICA 555 ceramoplastic. The total dimensional stability of the insulation reduces the receiver's frequency drift to only .015% (32.5 - 57.5 mc) over a temperature range from —55° C to +75° C. This, in effect, doubles the number of usable channels on the equipment's allotted frequency by permitting 50 kc adjacent channel operation.

Crosley engineers conducted extensive tests before specifying SUPRAMICA 555 ceramoplastic and found that **no other insulating material** provided all the properties required: mass reproducibility with negligible variations, extremely low electrical loss, dependable high temperature operation, insignificant moisture absorption, high dielectric strength and total dimensional stability.

This is just one of thousands of SUPRAMICA ceramoplastic products, produced by MYCALEX CORPORATION OF AMERICA for leading manufacturers. The special formulation of SUPRAMICA . . . high quality electrical glass--bonded with SYNTHAMICA,* synthetic mica . . . can help solve many of your design problems. Send for full technical information.

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METAL FILM RESISTORS

The Welwyn Welmet provides considerably greater stability than is obtainable in deposited carbon types. A Welmet, in fact, closely approximates the stability of a wire-wound resistor, yet is smaller in size and lower in cost.

Resistance Range . . 1000 to 1,000,000 ohms.

Tolerance . . . ±1%, ±2% or ±5% — closer tolerance in matched pairs can be supplied to special order.

Stability . . . The resistance value will not change more than 0.05% over a period of six months.

Stability Under Load . . . The long term change in ohmic value due to full power loading will not exceed 0.1%.

Temperature Coefficient:
The temperature coefficient depends on resistance value, and lies between 300 and 360 parts per million per degree centigrade. The coefficient is positive in all cases, and in general the lower ohmic values have the higher temperature coefficient in the stated range.

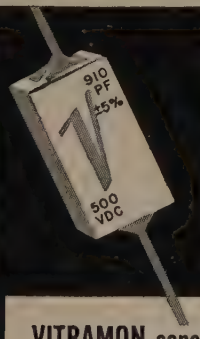
Welwyn Welmet resistors are available in small production quantities for test and laboratory purposes.

Complete specifications and prices on request Dept. PC-4

Welwyn International, Inc.

3355 Edgecliff Terrace, Cleveland 11, Ohio

manufactured in England and Canada



Vitramon® CAPACITORS

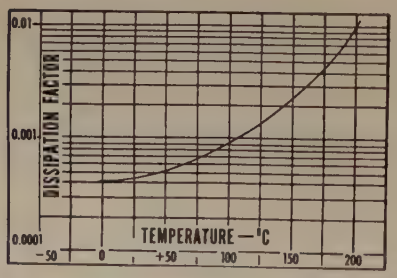
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WIDE TEMPERATURE RANGE

. . . into your circuit systems

VITRAMON capacitors . . . fine-silver electrodes fused to pure porcelain enamel dielectric . . . operate predictably over a range of more than 300°C and come back from the extremes — unaltered.

VITRAMON capacitors have low dissipations from —55°C to 250°C.



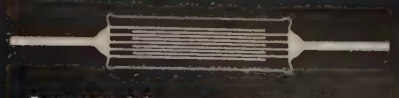
WIDE TEMPERATURE RANGE?

YES! PLUS . . .

RUGGED LOW LOSS STABLE
VAPORPROOF
LOW NOISE MINIATURE

The biggest names in electronics use VITRAMON capacitors in guided missiles, jet ignition, proximity fuses and in radar, servo, guidance, fire control, telemetering and carrier telephone systems.

If substitutes are not good enough . . . if you need the best . . . write today!



Two materials — a monolithic block of porcelain enamel and fine-silver electrodes — fused into one strong, stable, efficient and effectively homogenous **RELIABLE** unit.

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Whom and What to See at the Radio Engineering Show

(Continued from page 236A)

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Electronics & X Ray Div.
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Woodside 77, N. Y.
Booths 3715-3717

Charles Zavales, ▲ John Ebert, ▲ Martin Kaplan, ▲ Neal Deoul, Dan Kirshner



Direct Reading MM Attenuator

New—first showing by FXR—precision waveguide attenuators, precision direct reading frequency meters, BWO power supply, microwave signal sources, audio function generator, high power pulse modulators plus other additions to the complete FXR line of Precision Microwave Test Equipment.

Fairchild Guided Missile Division Fairchild Engine & Airplane Corp., Booth 1911
118 East 16th St.
Costa Mesa, California

Line analyzer-Model 303. Transistor Analyzer, Decade Amplifier, Transistor Curve Tracer, Federal Tel Switchboard Case, GE Case with a piece of electronic equipment, resistance Bridge Indicator and Bridge Balance.

Fairchild Engine & Airplane Corp., Booth 1911
118 East 16th St.
Costa Mesa, California

Howard E. Roberts

Plastic microwave guides, potentiometers, channel plotter.

Fairchild Controls Corp., Booths 2501-2503
Components Div.
225 Park Ave.
Hicksville, L.I., N. Y.

A. A. Budde, ▲ R. J. Sullivan, F. C. Weiss, Jr., H. J. McCann, R. Glueck, E. J. Breen, H. Cashman, H. Avey, E. Hicks, H. Schaad

High Temperature Pressure Transducer Precision-Potentiometers-wire-wound and metal-film; linear and functional; single and multi-turn rectilinear, and trimmer types. High temperature line. *Pressure transducers and *accelerometers.

Fairchild Publications, Inc., Booth 4024
7 East 12th Street
New York 3, N. Y.

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Fairfield Engineering Corp., Booth 3054
Briar Brae Road
Stamford, Conn.

A. Gutterman, C. Baker, L. Gutterman

Thyratron grid drive. A new packaged grid control circuit. Fast one cycle response. AC or DC input. For all your thyratron control applications.

(Continued on page 241A)

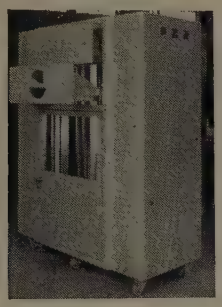
* Indicates new product.
▲ Indicates IRE member.

Whom and What to See at the Radio Engineering Show

(Continued from page 238A)

Falstrom Co.
Falstrom Ct., Passaic, N. J.
Booths 4501, 4503

C. F. Lindholm, A. A. Lindholm, C. F. Lindholm II, R. E. Hill, J. E. Jensen, W. H. Muench, H. P. Stuart



Cabinet with pull-out type chassis and drawers

Aluminum and magnesium fabrication for the electronics industry. Falstrom standard and custom built cabinets, consoles, frames, racks, chassis, and cubicles.

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Booth 4021

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Farnsworth Electronics Co.
3702 E. Pontiac St.
Fort Wayne, Indiana

Booths 2510-2625

Iatron radar projector. Visible heat detector.

Federal Shock Mount Corp., Booth 2806
1060 Washington Avenue
New York 56, New York

Sol Silverman, J. Silverman, S. Andrews, Sol Kamin, A. J. Bondarenko, ▲ H. Friedman, J. Feigen, S. Balan, H. Zwiren.

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Federal Telecommunication Labs
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Nutley 10, N. J.
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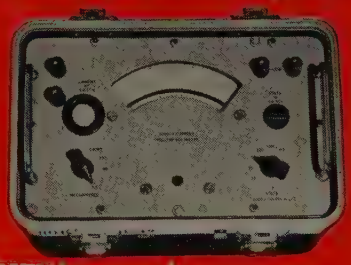
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Wide band over the horizon microwave. Vortac-Tacan air navigation systems. Traveling wave tube. (Conventional and miniaturized). Semi-conductors. Special pulse and microwave cable.

(Continued on page 242A)

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First
in ELECTRICAL
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NEW Ruggedized! Water-proof! D.C. Polyranger.



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NEW Core Less Test Set for magnetic measurements.



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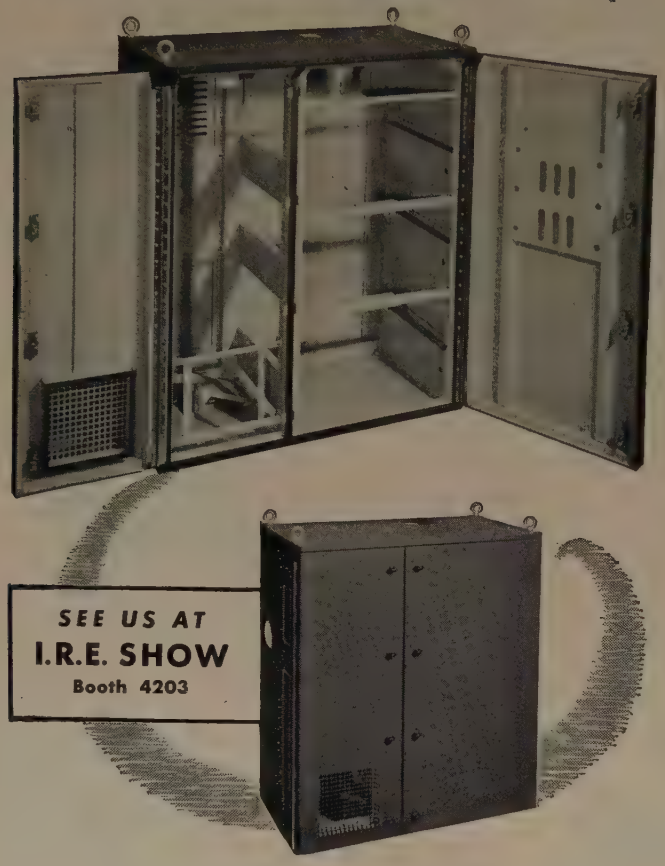
NEW Polyphase Wattmeter. Edgewise panel mount.

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Are your sheet metal housings of this quality—Are they being delivered according to schedule—and competitively priced?

We're producing many electronic cabinets . . . some much smaller, a few larger but all are quality through and through!

Whether yours is an individual "custom job" or a long production run, R & T's complete, modern facilities and vast cumulation of equipment and skill can *save you money*. Investigate, today!

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VENTILATION,
AIR CONDITIONING

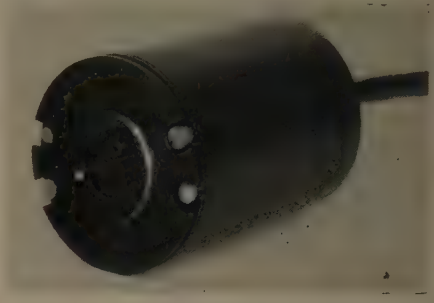
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Whom and What to See at the Radio Engineering Show

(Continued from page 241A)

Federal Telephone & Radio Co.
(Apparatus Division)
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Booths 2510-2625

C. Haltof, E. Ryan, F. K. Hankinson, R. S. Lehman, R. W. Bradley, G. G. Richardson, R. J. Fichthorn



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Digital converter. Loran receiver. Vortac air navigation system. Tacan air navigation system. Tacan test sets. Microwave equipment. Printed circuitry.

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J. E. Van Wagenen, A. M. Liebschutz, J. A. Staluppi, R. T. Reid, J. Conto



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High temperature rectifiers. High density rectifiers, contact protector rectifiers.

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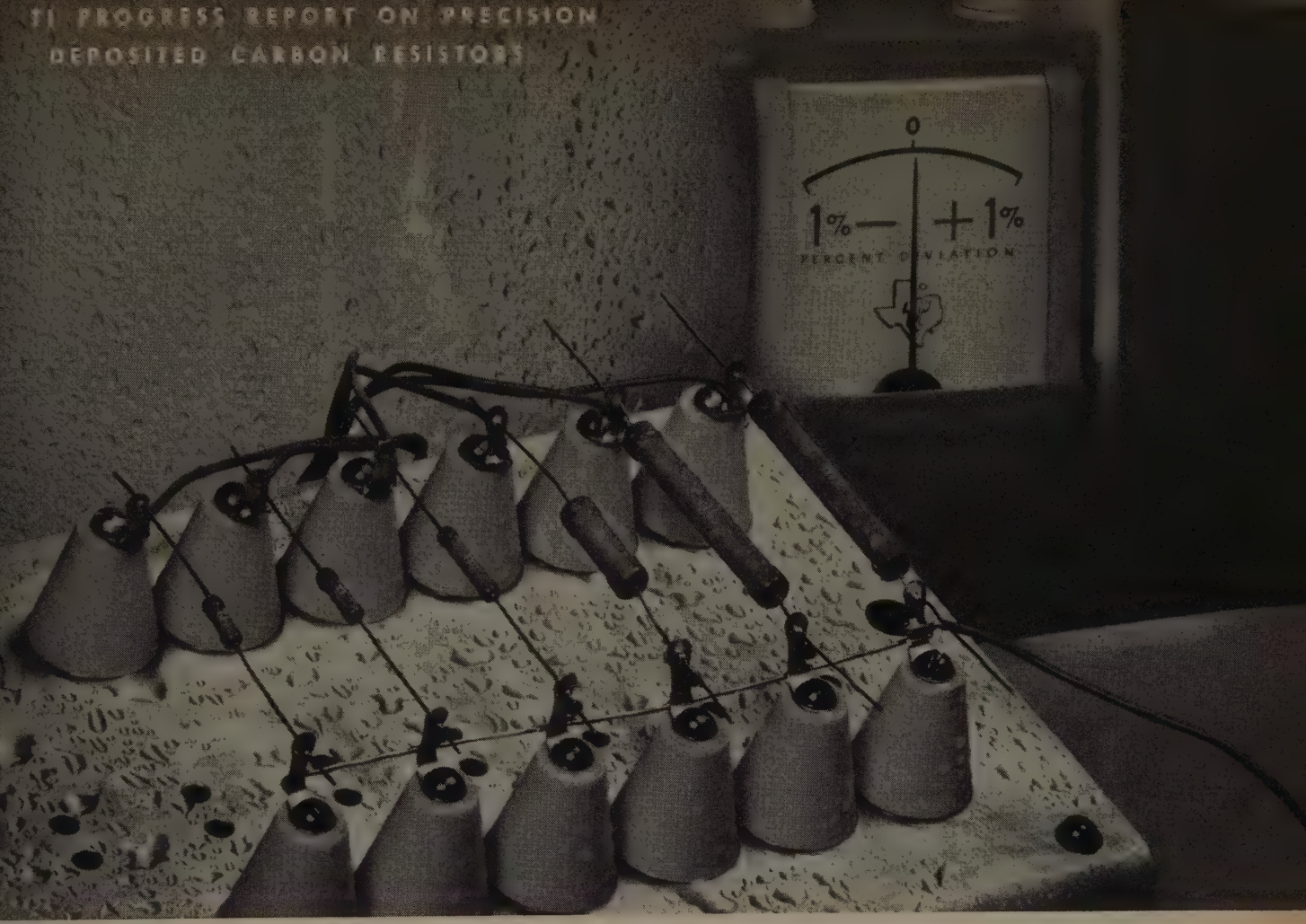
R. Feldt, R. C. Hess, J. B. Reynolds, T. Chabrack



Large Screen Oscilloscope

Large screen oscilloscope. Swept frequency generator. 40 channel bar graph oscilloscope. Frequency synthesizer. Diagraphs. Precision bridges. Field intensity meters. Tera-ohmmeters.

(Continued on page 244A)



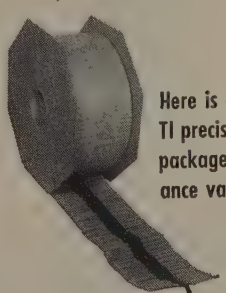
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HOLD TOLERANCE...EVEN WHEN DRIPPING WET!

Soaking wet, dried out, or 'shook up' — TI MIL-Line deposited carbon resistors still far exceed MIL-R 10509B . . . emerge from one acceptance test after another — by major electronics manufacturers — with performance records that have not been equalled. *It's the seal that makes the difference* . . . an exclusive Texas Instruments process that snugly wraps these precision resistors in tough jackets of a special coating with high dialectric strength.

For ease in design, production, and maintenance . . . for improving the reliability and saleability of your products, the moisture resistance of TI deposited carbon MIL-Line resistors is just *one* field-proven factor. You also get a choice of 1, 2, or 5% tolerances . . . high stability over wide temperature ranges and under full load . . . low negative temperature coefficients . . . negligible voltage coefficient and noise levels . . . long shelf-life . . . wide selection of sizes and resistance values . . . reasonable prices . . . and, if desired, reel-type packaging for automation.

Visit our booths No. 2816 to 2820 at the 1957 I.R.E. Show, New York

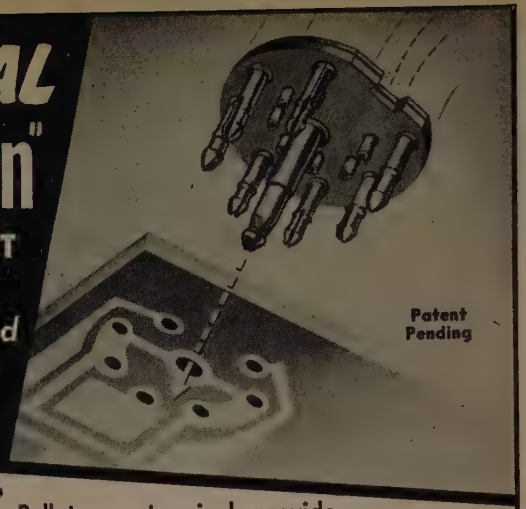


Here is a typical TI reel pack designed to speed production. TI precision deposited carbon resistors are mass produced and packaged in five sizes from ½ watt to 2 watts with resistance values from 25 ohms to 30 megohms.

For complete data, write for Bulletin DL-C 539.

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INCORPORATED
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INDUSTRIAL
"Automaton"
PRINTED CIRCUIT SOCKET
First socket designed expressly for AUTOMATION...



Easy Insertion • Bullet nose terminals provide for easy location and insertion.

Mechanical Lock-in • Notches in terminals provide for locking of sockets into chassis. Will not loosen with vibration or handling.

Perfect Solder Joint • Round terminals contact copper foil on entire circumference of chassis hole.

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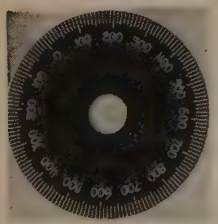
IRE SHOW BOOTH 2715

Opening between socket and chassis provides for good heat dissipation. Available in 7 and 9 pins; also available with tube shield clip.

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Manufacturing Company, Inc.
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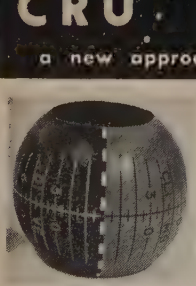
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a new approach to marking of counter wheels, drums and spheres.

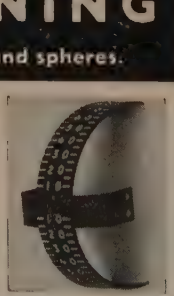


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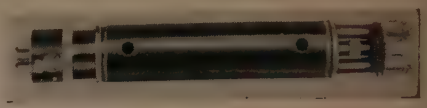
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Whom and What to See at the Radio Engineering Show

(Continued from page 242A)

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Booths 2510-2625

W. C. Schmitt, R. W. Deusch, K. R. Liddane



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A * basic oscillator and amplifier unit that forms a foundation for additional items as required.

(Continued on page 246A)

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PROVIDES MAXIMUM SHIELDING EFFECTIVENESS
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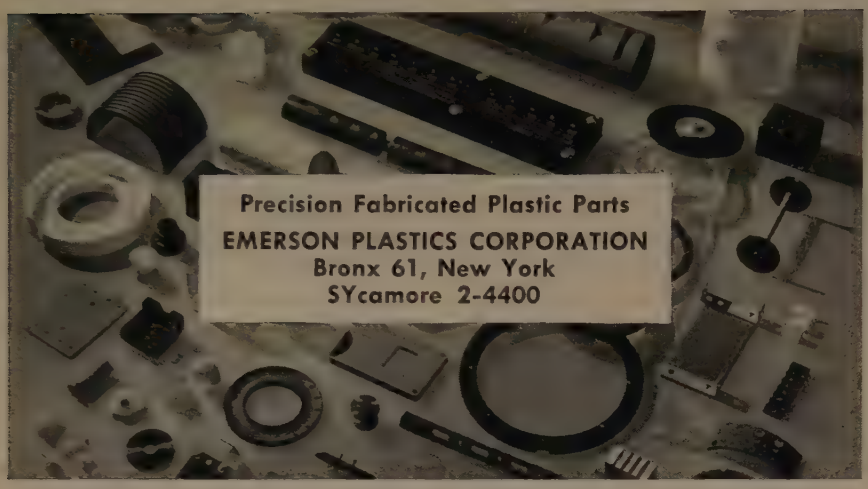
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IRE Show

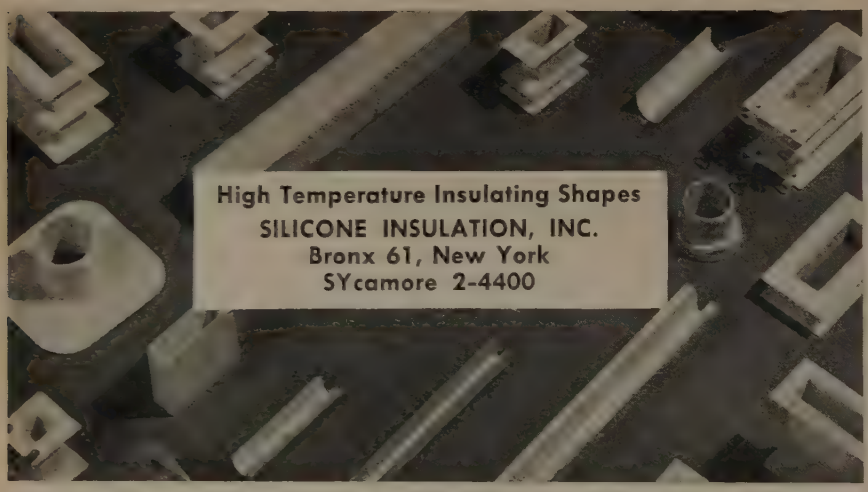
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Whom and What to See at the Radio Engineering Show

(Continued from page 244A)

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Pot cores and recording head cores for high reliability components in computers and carrier equipment, cores for HF power transformers, TV flybacks, shielding, pulse transformers, chokes.

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Port Washington, N. Y.
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(Continued on page 248A)

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Second Floor—Component Parts
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A wide range of dependable, fixed, adjustable, tapped, and noninductive power wire-wound resistors. Also a wide range of precision resistors.

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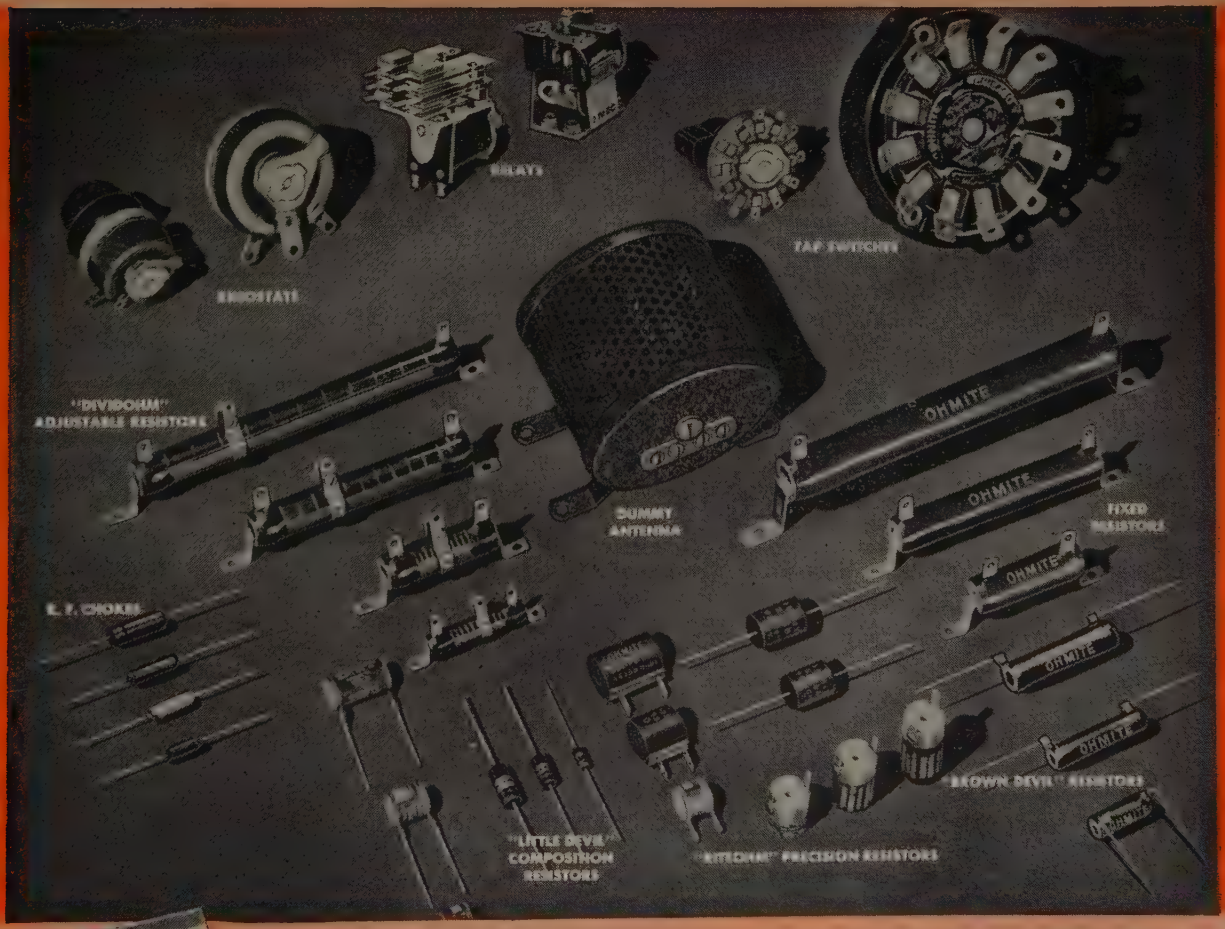
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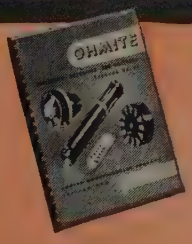
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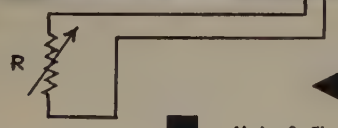
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$E_o = KR$

The above simple relationship exists between the Inserted Resistor and the Output Voltage where $K = \frac{1}{1000}$

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Main & Fine Control / Super Regulation
Full Range use for all Load Conditions
Remote or Local Control
Auxiliary Bias and Filament Output

This all new system* for the first time permits local or remote control operation with no loss of performance. Ideal for test consoles, automation, etc. Priced low enough for general purpose use.

TYPICAL MODELS

	VOLTS	CURRENT	REGULATION	RIPPLE	SIZE H	W	D
231A	0-300 V	0-100 MA	0.1% or 0.1 V	1 MV	7	19	11½
232A	0-300 V	0-200 MA	0.1% or 0.1 V	1 MV	7	19	11½
233A	0-300 V	0-200 MA	0.1% or 0.1 V	1 MV	7	19	11½

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Whom and What to See at the Radio Engineering Show

(Continued from page 246A)

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R. Graham, H. Niles, W. Warner, W. Weber, J. Coleman, J. Barrett



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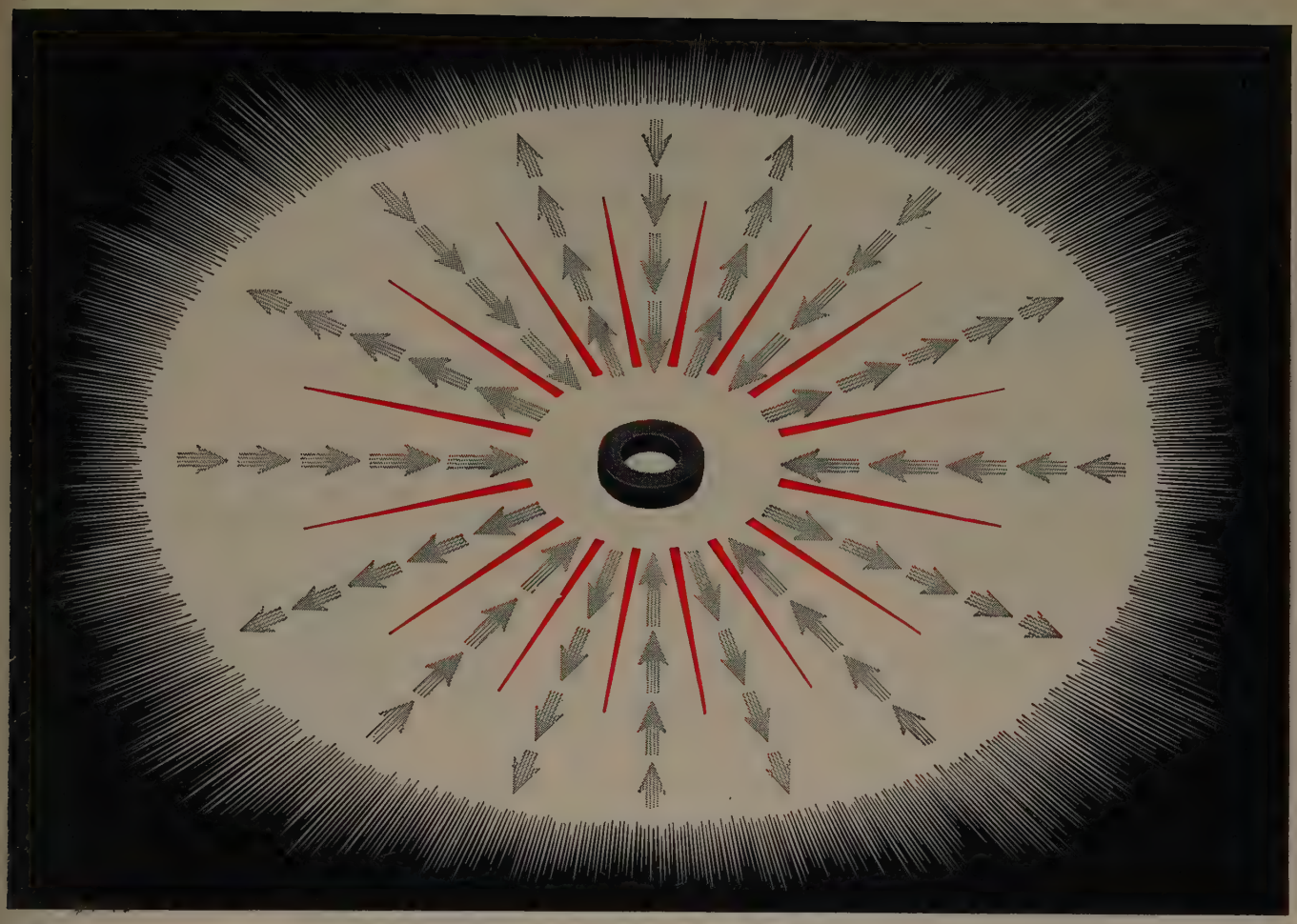
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*Magnetic amplifiers, *High "Q" toroids, *ultrasonic converters, *electronic counters, *High temperature 200° C. transformers, *reference transformers.

Furst Electronics, Booth 3033
See: Electric Eye Equip. Co.

(Continued on page 250A)

* Indicates new product.
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RCA TRANSFLUXORS . . . this developmental memory device, *originated by RCA*, utilizes a ferrite core, has two apertures, and exhibits a nearly rectangular hysteresis loop. It can control the transmission of ac power according to a level established by a single setting pulse. It furnishes an output determined by the stored pulse for *an indefinite* length of time. Once set the TRANSFLUXOR does not require an input command to furnish output intelligence.

RCA DEFLECTION FERRITES . . . for television, radar and industrial TV, "C" frames, yoke segments and toroids in standard or superefficient types.

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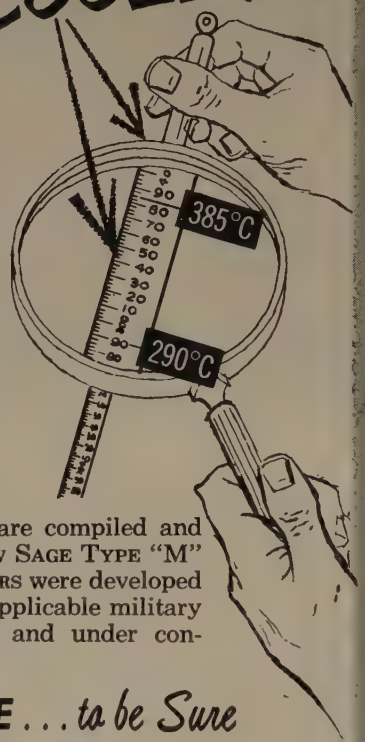
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RADIO CORPORATION of AMERICA

COMPONENTS DIVISION — CAMDEN, N. J.

NOW A METAL-CLAD CHASSIS-MOUNTED RESISTOR THAT ACTUALLY OPERATES

25% COOLER



Thanks to an improved potting technique which affords better heat conduction and dissipation, the internal HOT-SPOT temperature of SAGE TYPE "M" actually has 25% less rise than has been previously available in metal-clad, chassis-mounted resistors.

This cooler HOT-SPOT means longer life, improved stability, greater all-around reliability. Dielectric strengths up to 2500 VRMS are obtainable.

Engineering, test, and application data on many of the novel aspects of this style of resistor are compiled and awaiting your inquiry. These new SAGE TYPE "M" (metal-clad) "SILICOHM" RESISTORS were developed to meet the requirements of all applicable military specifications currently existing and under consideration.

Specify **SAGE** *. . . to be Sure*



50 WATT
0.3 to 60,000 Ohms

25 WATT
0.1 to 16,000 Ohms
Tolerances from 3% to .05%

Complete data available on request.

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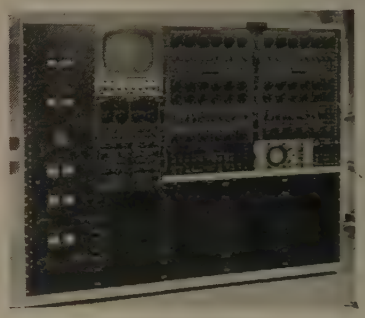
Whom and What to See at the Radio Engineering Show

(Continued from page 248A)

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The 14E Automatic Component "Wire-Wrap"® Machine for automatically attaching pig-tail components to terminal boards will be in continuous operation at our exhibit. Hand held air and electric Keller "Wire-Wrap"® tools for making solderless electrical connections will also be demonstrated.

(Continued on page 252A)

* Indicates new product.
▲ Indicates IRE member.

TUNG-SOL *Alloy Junction Germanium Transistors*

Reliability is the principal characteristic of these hermetically sealed Tung-Sol transistors now in volume production. Gain factor is extremely high over the operating ranges, with excellent heat dissipation. Design and construction methods provide a wider safety margin against the effects of shock, vibration, contamination and temperature. Rigorous testing of electrical and mechanical characteristics assures accurate maintenance performance and life standards. If your equipment designs call for transistors of these or related types, you will find Tung-Sol quality and dependability extremely valuable in maintaining your own output at highest levels.



HIGH POWER TRANSISTORS



	RATINGS (25°C)		TYPICAL CHARACTERISTICS (25°C)			
	V_c	P_c	Current Gain 500 MA Ice	Power Gain CL. A	Power Output CL. A	Distortion Max.
TS176	—30 Volts	10 Watts	50db	32db	2.5 Watts	5%

Type TS176 PNP junction transistor is designed for high power audio service in mobile battery operated equipment. The collector is connected directly to the case for conduction cooling. Emphasis is given to efficient thermal design, high power sensitivity, low distortion at high current levels and reliable hermetic sealing.

TS612
TS613

These are high power units rated for non-audio applications such as series regulator and power switching. Collector-to-emitter voltage ratings range from 50 to 90 volts depending on circuit conditions.

MEDIUM POWER TRANSISTORS



	RATINGS (25°C)			TYPICAL CLASS B OPERATION (25°C)		
	V_c	P_c	E_{cc}	Power Output	Distortion Max.	Power Gain
TS616	—25 Volts	150 MW	—12 Volts	500 MW	5%	28 db
TS617	—25 Volts	150 MW	—12 Volts	500 MW	5%	31 db
TS618	—25 Volts	150 MW	—12 Volts	500 MW	5%	34 db

PNP alloy junction transistors designed and tested for medium power class B audio applications. Close parameter control, particularly at high collector currents, makes special matching within type classification unnecessary.

	RATINGS (25°C)		TYPICAL CLASS A OPERATION (25°C)			
	V_c	P_c	E_{cc}	Power Output	R_L	Power Gain
TS619	—25 Volts	75 MW	—12 Volts	2 MW	15,000 OHMS	44 db

PNP alloy junction transistors designed and tested for class A driver service in audio amplifiers. Close parameter control and hermetic sealing insure production uniformity and performance stability.

General Purpose Transistors: The following general purpose RETMA types are also available: 2N63, 2N64, 2N65.

Other semiconductor devices being developed for production include these important types:

Germanium transistors of both PNP and NPN types, designed for computer switching and radio frequency applications.

Germanium PNP medium power transistor with 350 milliwatt dissipation rating.

Gold bonded germanium computer diode.

Silicon power diode with diffused junction.

More Data? Requests for additional information about these—and other related types of transistors for special applications—should be addressed to: Semiconductor Division, 95 Eighth Avenue, Newark 4, N. J.

Technical Information Service. Upon request, your name will be placed on our special mailing list. You will automatically receive new Tung-Sol semiconductor data and product application notes as such information becomes available.

See You At The IRE Show! The Tung-Sol Booth is 2813-15. It will feature actual assembly of electron tubes and semiconductors.

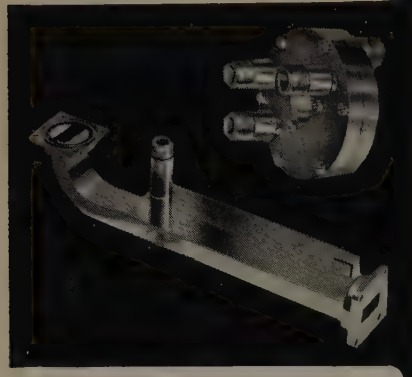
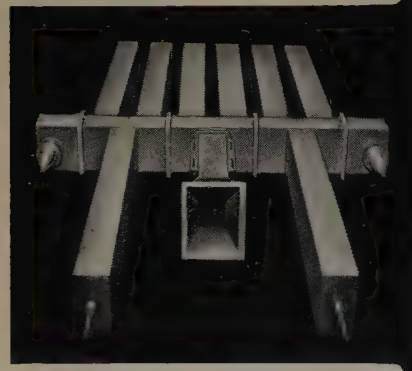
CAREER OPPORTUNITIES

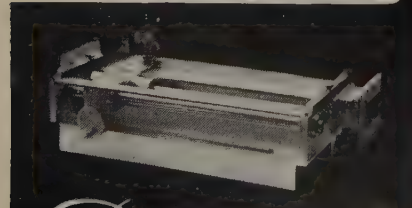
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Whom and What to See at the Radio Engineering Show

(Continued from page 250A)

Gates Radio Company
123 Hampshire St.
Quincy, Ill.
Booths 1302-1308

Larry Cervone, Norbert Jochem, Ed Wilder, Wally Warren, Phil Nesbitt, Bob Hallenbeck, J. R. Eickmeyer

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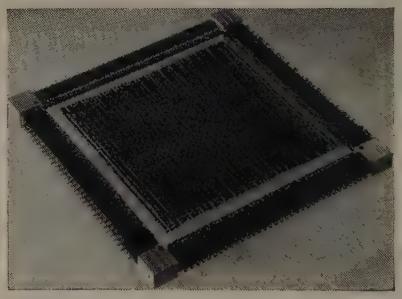
General Bronze Corp., Booth 1109
711 Stewart Ave.
Garden City, N. Y.

▲ Ira Kamen, ▲ George Doundoulakis, Vito Capuco, ▲ Martin Kanner, ▲ Joseph Fradkin, ▲ George Reinhardt, Arthur S. Jordan, Robert A. Burri

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General Ceramics Corp.
Crows Mill Road, Keasbey, N. J.
Booth 1319

▲ Mr. C. L. Snyder, Mr. John Manley, Mr. James Shallerer, Mr. Harold Landsberger, Mr. Norman Shapiro.



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General Ceramics new magnetic memory frames feature greater strength and rigidity. New assembled construction makes frames of any size ready available. Spacers not required in vertical construction.

General Communication Co.
681 Beacon Sreet, Boston 15, Mass.
Booth 3063

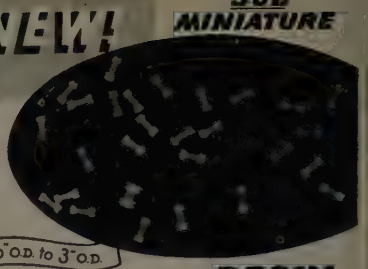
▲ Joseph L. Weis, Ronald N. Jones, J. B. Humre, ▲ J. H. Woodward, B. H. Sinclair, J. M. Orsillo



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GCC'S Pulse Power Calibrator Model PCX-1, Joined by two new members. PCX-3 and PCX-9, "S" and "X" band models. Coaxial switches and radar beacons available also.

(Continued on page 254A)

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- Special sizes and shapes, miniatures and large, to meet your exact requirements.
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Whom and What to See at the Radio Engineering Show

(Continued from page 252A)

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New York 51, New York

Booth 4048

Henry Meola

Terminals, terminal boards, electrical hardware.

General Electric Co.
Apparatus Sales Div.
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Schenectady, N. Y.

Booths 2904-2932

Specialty capacitors, rectifiers, specialty control, aircraft motors, voltage regulating equipment, and recorders and instruments for vacuum systems. The new type M-1 Mass Spectrometer Leak Detector will also be shown.

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Ashland, Mass.

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The "Doze-Alarm" and the "Miniature" radio timers. The "Doze-Alarm" insures those extra forty winks and the "Miniature" is a natural for smaller transistor radios. Plus a full line of Telechron timers and Motors for appliances.

General Electric Co.
Electronics Components Dept.
Syracuse, N. Y.

Booths 2904-2932

▲ D. Yost, ▲ R. J. Biele, ▲ L. E. McFarren

Thru-Con Print Wire Boards; Their construction, their application in Electronic and Allied industry. Precise engineering advice on Print Wire problems.

General Electric Co., Industrial Control Dept., Booth 2932
Roanoke, Virginia

G. R. Krunnacher, G. D. Dykhuizen

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General Electric Co., Industrial Heating Dept., Booth 2928
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New York, New York

R. A. Gehr, W. Warden

New Miniature electric soldering iron. Designed for use by electronics component manufacturers for miniaturized circuits and printed circuitry. ⅛" diameter tip and shank. 12 watts, 6 volts, vacuum processed tip, tiny tubular heater in tip for maximum efficiency and tip temp recovery rate.

(Continued on page 256A)

Show Hours
10 a.m. to 9 p.m.
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3 significant new PANORAMIC instruments

1 • Converts Panoramic Spectrum Analyzers to Power Density Analyzers

2 • Facilitates Dynamic Balance Analysis

3 • Offers new possibilities for miniaturization of FM/FM Telemetry Ground Stations

1 new **Model PDA-1 Panoramic's Spectral Power Density Analyzer** — A tremendously flexible instrument that expands the utility and versatility of Panoramic's Spectrum Analyzers from Sub-Sonic through Microwave . . . automatically analyzes the energy distribution of random information. Ideal for evaluating noise, vibration and other changing phenomena.

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3 new **Model TMC-307 Panoramic's 7-Point Frequency Calibrator**—Designed specifically for telemetering applications, the TMC-307 sequentially furnishes *seven* equally spaced frequencies per channel for all RDB channels within end limits of ± 7.5% . . . within ± 15% for the upper five channels. Other end limits and spacings can be furnished. Channel and frequency point switching may be either manual or automatic. Accuracy is 0.02%. Occupying only 10½" panel space, the Model TMC-307 offers new possibilities for miniaturized ground station equipment.

Pioneers in the field of spectrum analyzers from sub-audio to microwave, unparalleled sweep generator systems and highly reliable frequency calibrators, Panoramic instruments have accelerated completion of research and development projects and helped to clear production test bottlenecks.

Now, Panoramic again leads the way with these three new instruments, highly versatile and far reaching in application.

SEE these significant new instruments . . . get a glimpse of new equipment to come . . . learn how Panoramic's instrumentation for testing, checking or measuring problems can help you . . . in the laboratory, on the production line, or in military applications. You are also cordially invited to witness dynamic demonstrations and to discuss with our engineers technical characteristics and applications of panoramic instruments.

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Whom and What to See at the Radio Engineering Show

(Continued from page 254A)

General Electric Co.
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Booth 2928

E. T. Connor, R. F. Connolly, J. W. Hinchliffe

*Mass Spectrometer Leak Detector gives unsurpassed leak sensitivity (1×10^{-10} standard cubic centimeters of air per second). Two second response time. Simplified vacuum system and plug-in electronic components reduce down time.

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Waynesboro, Virginia

D. F. Cross, R. D. Hawkins, R. C. Gill, M. A. Foster

Hermetically sealed relays featuring micro-miniature size, light weight, long life, and unusual reliability under severe temperature, shock and vibration conditions.

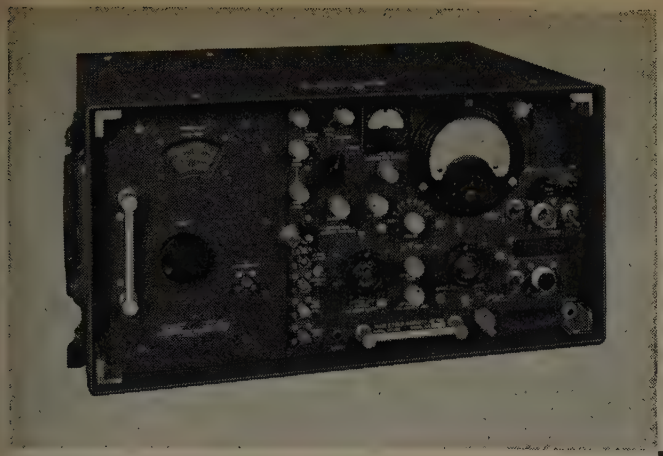
General Electric Co.
Tube Department
1 River Rd., Schenectady 5, N. Y.

Booths 2904-2932

See Five-Star high-reliability tubes actually assembled in hospital-clean "Operation Snow White." Voltage-tunable magnetron demonstration Crowbar circuit tubes.

(Continued on page 258A)

First Floor—Equipment
Second Floor—Component Parts
Third Floor—Instruments & Components
Fourth Floor—Production

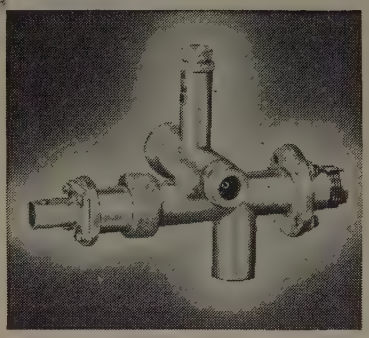


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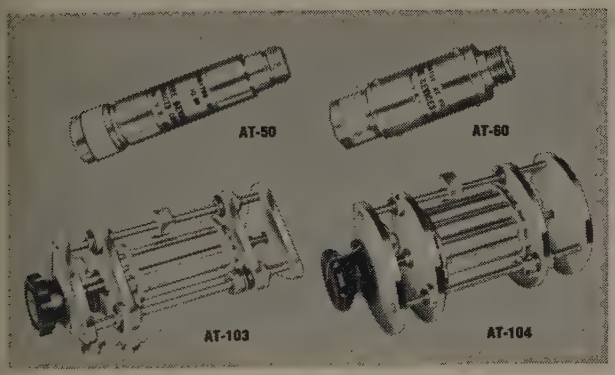
Four quick-change tuning heads • Single knob tuning for easy scanning Built-in impulse generator serves as calibrator • Carrier and peak reading VTVM • Aural slideback • Coaxial step attenuators • Regulated "A" and "B" supply.



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Broad Band, Fixed Tuned • 225 MC to 5600 MC in 8 models • Input and L.O. VSWR better than 2 to 1 • L.O. rejection at IF output better than 30 DB.

CRYSTAL DETECTOR, Model DT-123



UHF ATTENUATORS, Models AT-50, AT-60

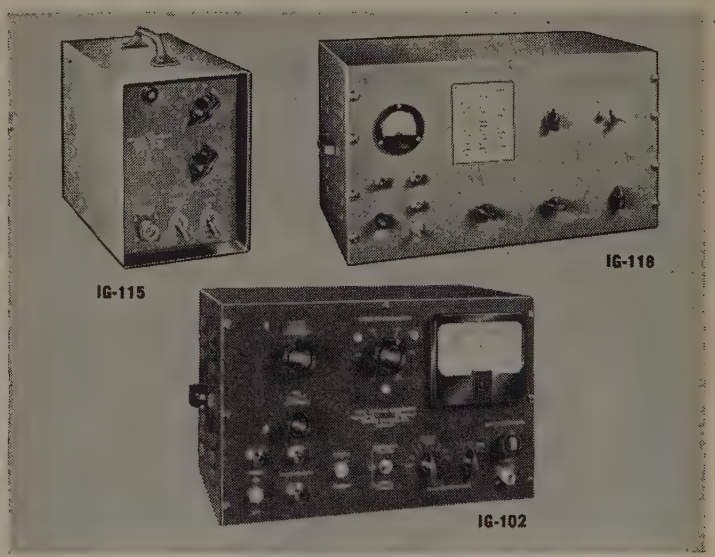
50 ohm resistive T-networks of concentric line construction.
FREQUENCY RANGE:
AT-50: DC to 4000 MC.
AT-60: DC to 3000 MC.
VSWR: Better than 1.2 at all frequencies.
ACCURACY: ±½ DB.
RATED POWER:
AT-50: 1W continuous
1KW peak
AT-60: 2W continuous
2KW peak

STEP ATTENUATORS, Models AT-103, AT-104

These units use AT-50 pads in 6 step and 12 step coaxial turret arrangements respectively.

COAXIAL TERMINATION, Model TE-80

1 watt, DC to 4000 MC.



UHF IMPULSE GENERATORS, Models IG-102, IG-115, IG-118

Model	Flat Spectrum (±½ DB)	Peak Output Level	Repetition Rate
IG-102	10 KC to 1000 MC	70,000 μV/MC	2.5 to 2500 cycles
IG-115	10 KC to 1000 MC	100,000 μV/MC	60 cycles
IG-118	100 MC to 10,000 MC	9,000 μV/MC	2.5 to 2500 cycles



VARIABLE FREQUENCY POWER SUPPLY, Model VP-400

POWER OUTPUT: 500 watts
VOLTAGE REGULATION:
2%, no load to full load
HARMONIC DISTORTION:
5% maximum, total, (to 400W).

POWER DIVIDERS, Model PD-90

FREQUENCY RANGE: 800 to 10,000 MC in 5 models.



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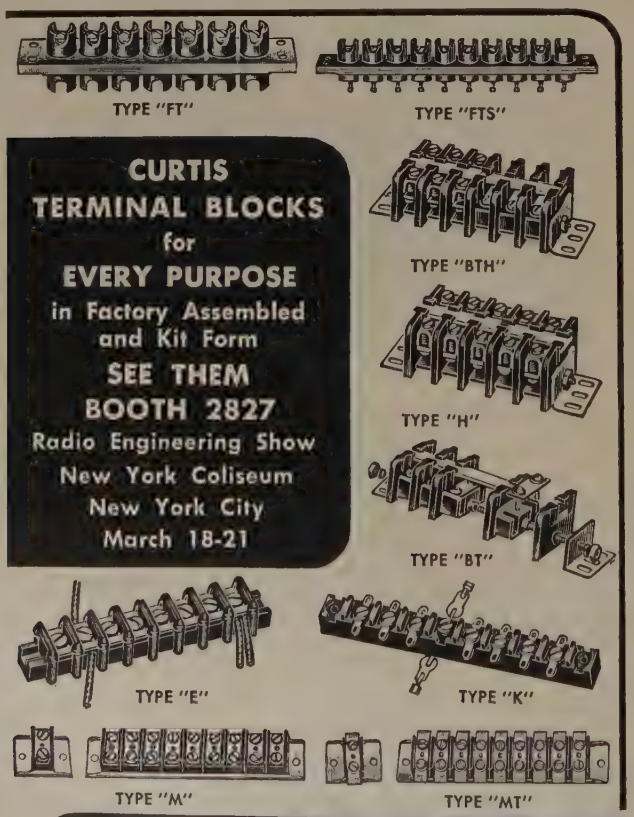
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3234 North 33rd Street, Milwaukee 16, Wisconsin

Whom and What to See at the Radio Engineering Show

(Continued from page 256A)

General Electric Co., Ltd., of England
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Booth 2003

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Engineering products, components & solderless breadboarding system, electronic kit.

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Gerald F. Tucci, Joe E. Doescher, Samuel Greenbaum

Precious Metal Contacts: Springs, Rivets, Micro-Brushes, Slip Rings, Assemblies, Alloys of Gold, Silver, Platinum and Palladium Precision Fabrications for Potentiometers, Synchros, Relays and Switches.

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Kenneth Meinken

High Reliability Hermetic Sealed Paper and Mica Capacitors, Low cost printed circuit stand-up paper tubulars, dipped paper radiation resistant capacitor 175°C.

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W. E. Gilman

Permanent magnets and their application.

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Booth 1425

A. B. Driscoll, J. A. Roegge, Paul Peterson, Edmund E. Johnson, A. A. Brevaire

The new "Autofab" Soldering Machine for selective forced soldering of printed circuit assemblies and the "Autofab" Assembly Machine for attaching components to printed circuits.

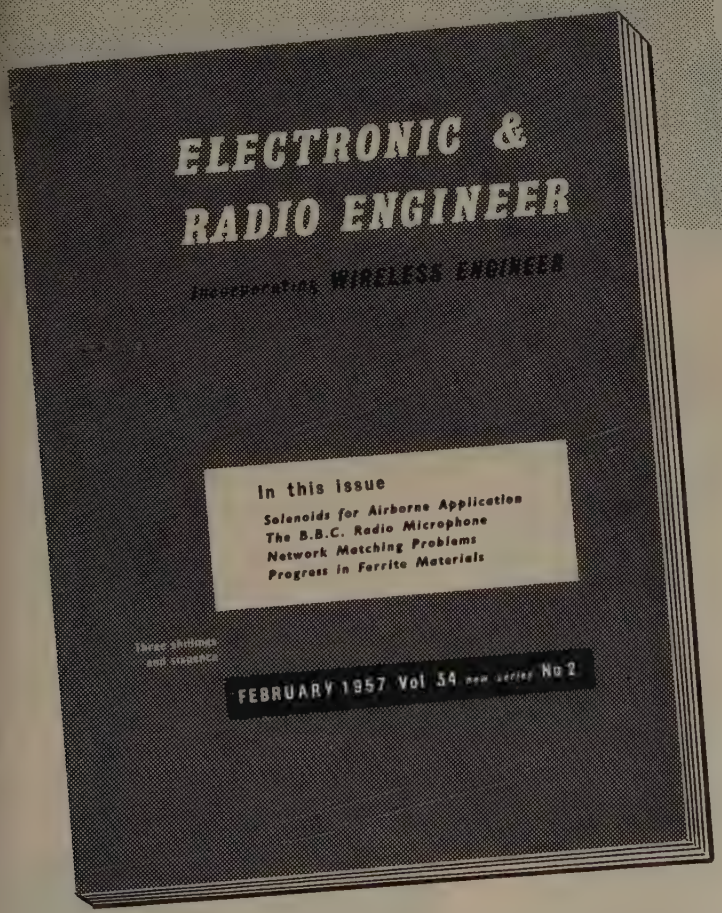
(Continued on page 260A)

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This selection of titles from the January and February issues gives an indication of editorial coverage

Phase-adjusting circuits
Selective admittance-measuring sets
Transducer characteristics
Transistor pulse generator
The B.B.C. radio microphone
Dilemmas in transmission-line theory
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Solenoids for airborne applications
Non-linear circuit equation



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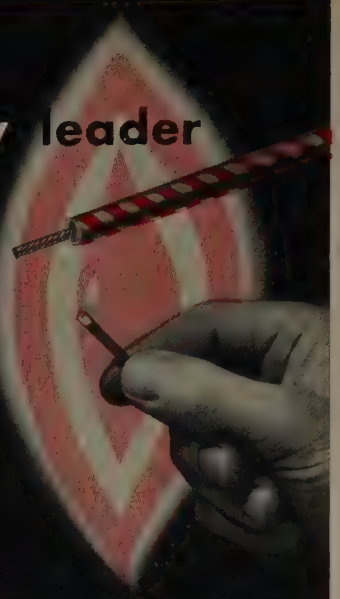
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(Continued from page 258A)

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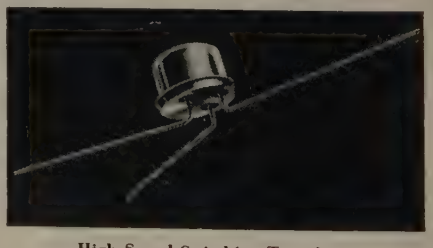


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General Transistor features a * Line of high speed switching Transistors for Computer applications; symmetricals; audio; Photo-Transistors.

(Continued on page 262A)

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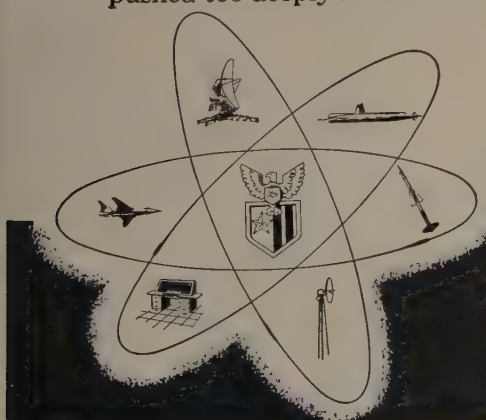
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Whom and What to See at the Radio Engineering Show

(Continued from page 260A)

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Shelley Krasnow, T. H. Greenburg, Raymond A. Prange



Nobrush Frequency Converter

Frequency Converter, 60 to 400 cycle, unit[*] shell. Light weight, compact, cool, efficient, quiet running two bearing construction. Brushless and trouble free. R.F. completely eliminated.

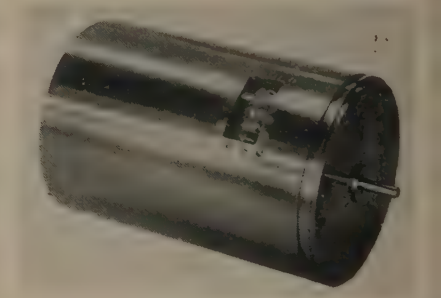
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(Continued on page 264A)

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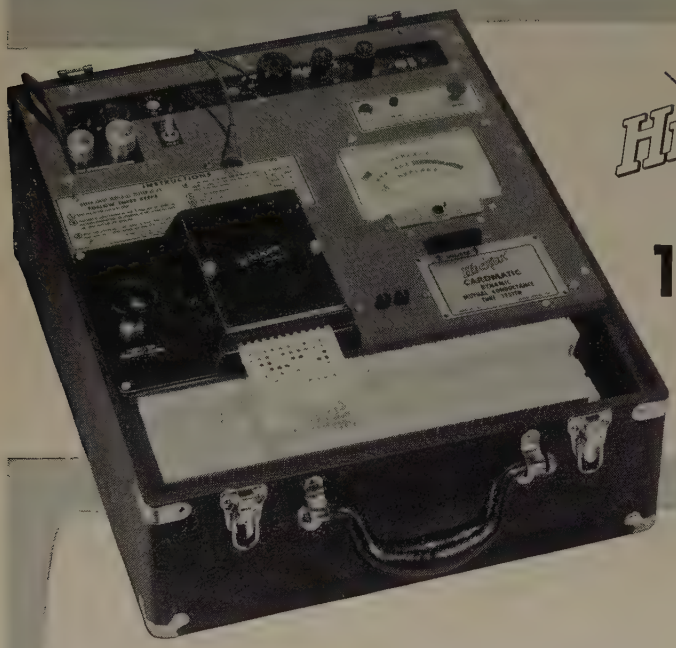
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Whom and What to See at the Radio Engineering Show

(Continued from page 262A)

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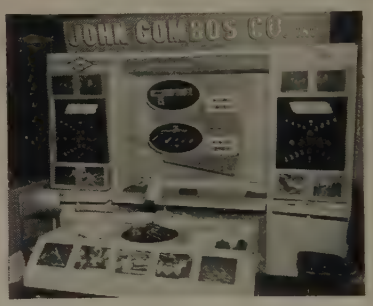
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Aaron Sivitz, Howard Isaacson, Yale J. Holt, George Offenbacker

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(Continued on page 266A)

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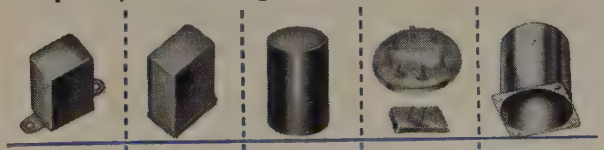
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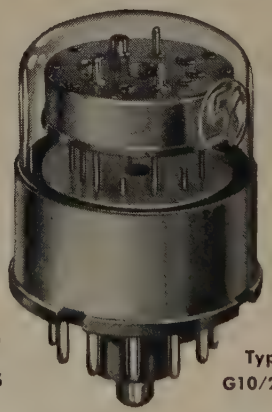
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(Continued from page 264A)

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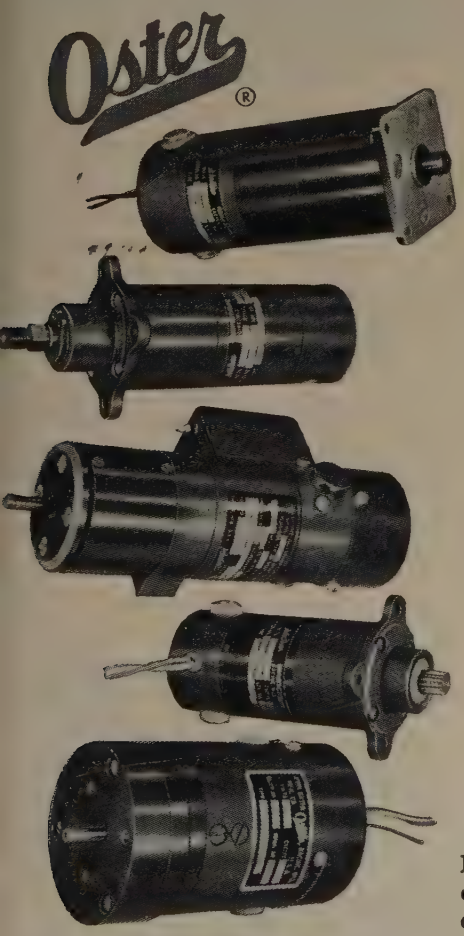
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Gear Ratio	No-Load Speed	Nominal Voltage D.C.	Voltage Range D.C.	No-Load Current	Normal Speed	Normal Load OZ.IN.	Normal Current	Operating Temp. Range					
5.68:1	1800	28	24-32	0.4	1800	5.0	1.0	−55° To +85°C	13	3.777	P.M. GOVERNOR	FACE	13R-9102-08
17.9:1	600	28	24-32	0.4	600	12.0	1.0	−55° To +85°C	13	3.930	P.M. GOVERNOR	FACE	13R-9102-06
32.3:1	300	28	24-32	0.4	300	12.0	1.0	−55° To +85°C	13	3.935	P.M. GOVERNOR	FACE	13R-9102-02
67:1	150	28	24-32	0.4	150	12.0	0.6	−55° To +85°C	13	4.092	P.M. GOVERNOR	FACE	13R-9102-05
85:1	150	27.5	—	.25	130	50.0	0.7	−55° To +85°C	13	4.095	P.M.	FACE	13R-9101-11
109:1	100	28	24-32	0.4	100	32	0.6	−55° To +85°C	13	4.094	P.M. GOVERNOR	SYNCHRO	13R-9102-12
109:1	180	27.5	—	0.4	175	30	0.5	−55° To +100°C	13	2.843	P.M.	FLANGE	13R-9104-01
125:1	75-90	28	—	.25	70-85	20	0.3	−55° To +71°C	13	3.920	P.M.	FACE	13R-9101-13
157:1	60	28	24-32	0.4	60	12.0	0.6	−55° To +85°C	13	4.095	P.M. GOVERNOR	FACE	13R-9102-03
285:1	48	35	—	.25	40	160	0.6	−55° To +71°C	13	4.038	P.M.	FACE	13R-9103-01
333:1	30	28	24-32	0.4	30	12.0	0.6	−55° To +85°C	13	4.317	P.M. GOVERNOR	FACE	13R-9102-04
410:1	15	27	25-29	0.3	15	8.0	0.3	−55° To +85°C	13	4.400	P.M. GOVERNOR	FACE	13R-9102-11
1043.8:1	5-10	27	24-30	0.15	7	30	0.2	−55° To +71°C	13	4.450	P.M. BRAKE	FACE	13R-9105-01
1044:1	5-10	27	24-30	0.15	7	30	0.2	−55° To +71°C	13	3.910	P.M.	FACE	13R-9101-12
2214:1	3-4	6	—	1.2	3.4	30	1.2	−55° To +71°C	13	4.454	P.M.	FACE	13R-9101-04
3241:1	5.5	35	—	.35	5.5	18	0.4	−55° To +71°C	13	4.454	P.M.	FACE	13R-9101-03
5933:1	1.3	30	—	.13	1.3	30	0.15	−55° To +71°C	13	4.816	P.M.	FACE	13R-9101-10
21,707:1	2-3	120	—	.25	2-3	12	0.25	−55° To +71°C	13	3.475	P.M.	FLANGE	13R-9101-16
322:1	80	110	—	0.2	30	240	0.3	−55° To +71°C	15	3.815	SPLIT SERIES	FLANGE	15R-9201-01
407:1	22	27	—	0.2	20	8	0.2	−20° To +50°C	15	3.989	SPLIT SERIES	SYNCHRO	15R-9201-03
433:1	30	26	—	0.6	25	260	1.2	−50° To +80°C	15	3.110	SHUNT	FACE	15R-9201-02
955:1	33	27	—	0.6	12-18	420	1.0	−55° To +50° C	15	4.419	SPLIT SERIES	FLANGE	15R-9201-08
26:1	240	27.5	24-29	0.65	240	40	1.3	−18° To +71°C	17	5.315	SHUNT GOVERNOR	SYNCHRO	17R-9251-01
4.26:1	1800	28	—	0.6	1800	12	1.85	−30° To +55°C	24	4.640	SHUNT GOVERNOR	FACE	24R-9451-01

Speed tolerance on governed motors is ±2% over voltage and an ambient temperature range. Closer speed tolerance units can be designed to fit the particular application.

Many other variations available. There is an Oster motor-gear-train to fit your exact specification. Consult Oster specialists today, sending your detailed requirements.

Other products include servos, synchros, AC drive motors, DC motors, servo mechanism assemblies, synchro indicators, servo torque units, reference and tachometer generators, actuators, motor driven blower and fan assemblies and fast response resolvers.

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Your Rotating Equipment Specialist
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Engineers For Advanced Projects:
Interesting, varied work on designing transistor circuits and servo mechanisms
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Available in different types and ratings; full and half-wave mercury vapor or gas filled, mercury vapor and gas, xenon others.



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Complete line of half-wave gas-filled grid control rectifiers . . . quick, sensitive, always dependable.



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Types to meet every requirement in dimensions and sensitivity to light and color.

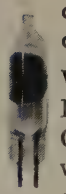


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Wide variety of Lead Sulfide Cells for uses where photo-emissive tubes are impractical.



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Whom and What to See at the Radio Engineering Show

(Continued from page 266A)

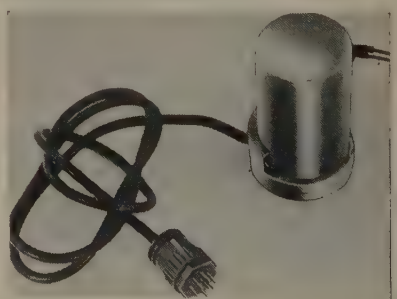
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Turning assemblies—rotary switches, pushbutton switches, thumbwheel switches, plug operated-printed wiring switches, T.V. tuners.

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Booths 2502, 2504
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* 25 ampere power relay with interchangeable coil assemblies requiring no solder connections.

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Tuners, amplifiers, communication receiver.

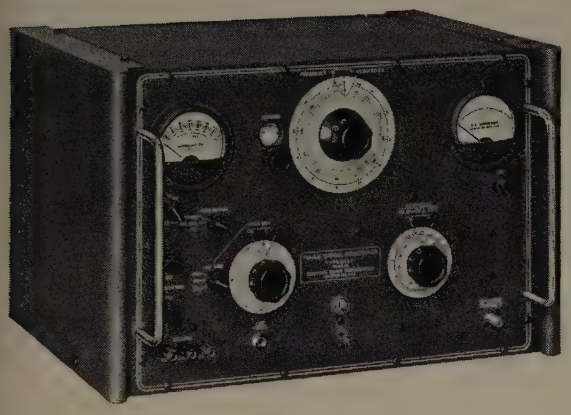
(Continued on page 270A)

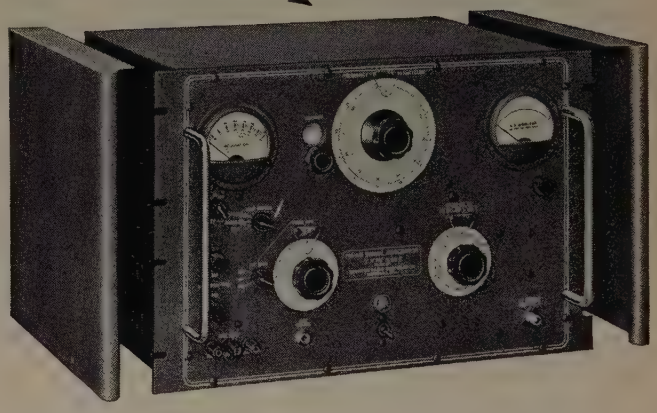
FM-AM TELEMETERING SIGNAL GENERATOR

Type 202-F 175-250 MC

DESIGNED FOR BOTH

BENCH USE AND RACK MOUNTING





RF RANGE: 175-250 Megacycles.

ACCURACY: ±0.5% after warm-up.

RF OUTPUT: Max. open circuit output voltage is approx. 0.4 volt. With output cable connected max. calibrated output voltage is 0.2 volt nominal. Min. 0.1 microvolt.

FREQUENCY MODULATION: Three frequency deviation ranges, 0-24 KC., 0-80 KC., and 0-240 KC. are provided, each continuously adjustable.

FM DISTORTION: The overall FM distortion at 75 KC is less than 2% and at 240 KC less than 10%.

FIDELITY CHARACTERISTICS: The deviation sensitivity of the FM modulation system as a function of frequency is flat within ± 1 db from 30 CPS to 200 KC.

AMPLITUDE MODULATION: Internal modulation available from 0-50% with meter calibration points at 30% & 50%. Using an external audio oscillator, the carrier may be amplitude modulated to substantially 100%. For this purpose the modulation meter has a scale calibration point at 100%. A front panel jack is provided which permits direct connection of an external modulation source to the screen of the final stage for pulse and square wave modulation.

INTERNAL AF OSCILLATOR: The internal AF oscillator provides either frequency of amplitude modulation; it may also be switched off. The internal AF oscillator provides eight fixed frequencies which may be selected by a rotary type switch — 50, 100, 400 cycles and 1, 5, 7.5, 10, 15 kilocycles, accurate to within 5%. Harmonic distortion, in general, is less than 0.5%.

UNIVERTER TYPE 207-F

The Univerter, Type 207-F, a frequency converter accessory with unity gain, is designed to provide additional frequency coverage from 0.1 MC to 55 MC when used with Signal Generator Type 202-F.



BOONTON RADIO CORPORATION

Boonton, New Jersey

PRICES:

FM-AM Signal Generator Type 202-F	$1075.00
Univerter, Type 207-F	$380.00

F.O.B. Boonton, New Jersey

Your Demands Created

HIGH VOLTAGE
SILICON POWER RECTIFIERS



Sarkes Tarzian series type SM silicon rectifiers provide the practical, low cost solution to the high voltage silicon rectifier problem. Stable characteristics inherent in low voltage junctions are carried over to this series. If your application calls for high temperature and high voltage, send for complete information.

ELECTRICAL RATINGS

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
80SM	800	560	450	.225	1.12	.560	4.5	2.25	27.0	13.5	1N1108
120SM	1200	840	.425	.212	1.06	.530	4.25	2.12	25.5	12.7	1N1109
160SM	1600	1120	.40	.200	1.00	.500	4.00	2.00	24.0	12.0	1N1110
200SM	2000	1400	.375	.187	.940	.470	3.75	1.87	22.5	11.2	1N1111
240SM	2400	1680	.35	.175	.875	.437	3.50	1.75	21.0	10.5	1N1112
280SM	2800	1960	325	.162	.812	.405	3.25	1.62	19.5	9.7	1N1113

DIMENSIONS

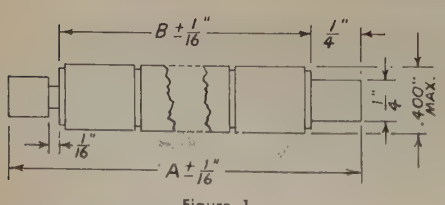


Figure 1

Figure 1 A	Figure 1 B	JETEC NO.
1-15/32"	31/32"	1N1108
1-15/16"	1-7/16"	1N1109
2-13/32"	1-29/32"	1N1110
2-7/8"	2-3/8"	1N1111
3-11/32"	2-27/32"	1N1112
3-13/16"	3-5/16"	1N1113

Sarkes Tarzian, INC.

RECTIFIER DIVISION

415 N. College Ave., Dept. P-1, Bloomington, Ind.

IN CANADA: 700 WESTON RD., TORONTO 9, TEL. ROGERS 2-7535
EXPORT: AD AURIEMA, INC., NEW YORK CITY

Whom and What to See at the Radio Engineering Show

(Continued from page 268A)

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See: Hathaway Instrument Div.

Hammarlund Mfg. Co., Inc.
460 W. 34th St.
New York 1, N. Y.
Booths 1212 & 1214

F. F. Sylvester, R. M. Daugherty, L. C. Menkes, F. Peters, F. Lester, J. Scheider

The precision line of air dielectric variable capacitors, communications receivers, centralized operations control—the 1st logical step to automation.

Hamner Electronics Co.
P. O. Box 531, Princeton, N. J.
Booth 3022

▲ Lloyd H. Hamner, Dale Kastle, Jack Stollman, Charles C. Townsend, ▲ Dr. Thomas Coor, ▲ Ervine M. Rips

* Gamma Ray Scintillation Spectrometer capable of very high counting intensities and a new function plotter of revolutionary design.

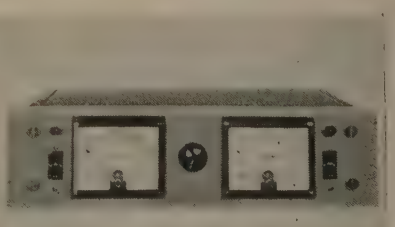
Hardwick, Hindle, Inc.
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Newark 5, New Jersey
Booth 3831

T. B. Ure, F. N. Sumrell, W. Wankmuller, H. O. Strand

Exhibit Features: Power wire wound vitreous enameled resistors and rheostats. Potentiometers—complete wattage range including "MIL". approved types.

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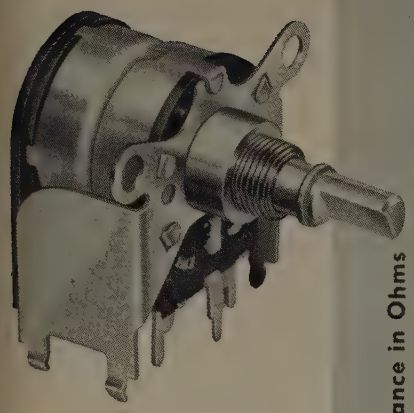
*700A, 3-300V, 1.5a, regulated power supply *800A, 2-30V, 500ma, regulated transistor supply *800B, 2-30V, 1.5a, regulated transistor supply *400D, 100-300V, 1.5a, regulated power supply.

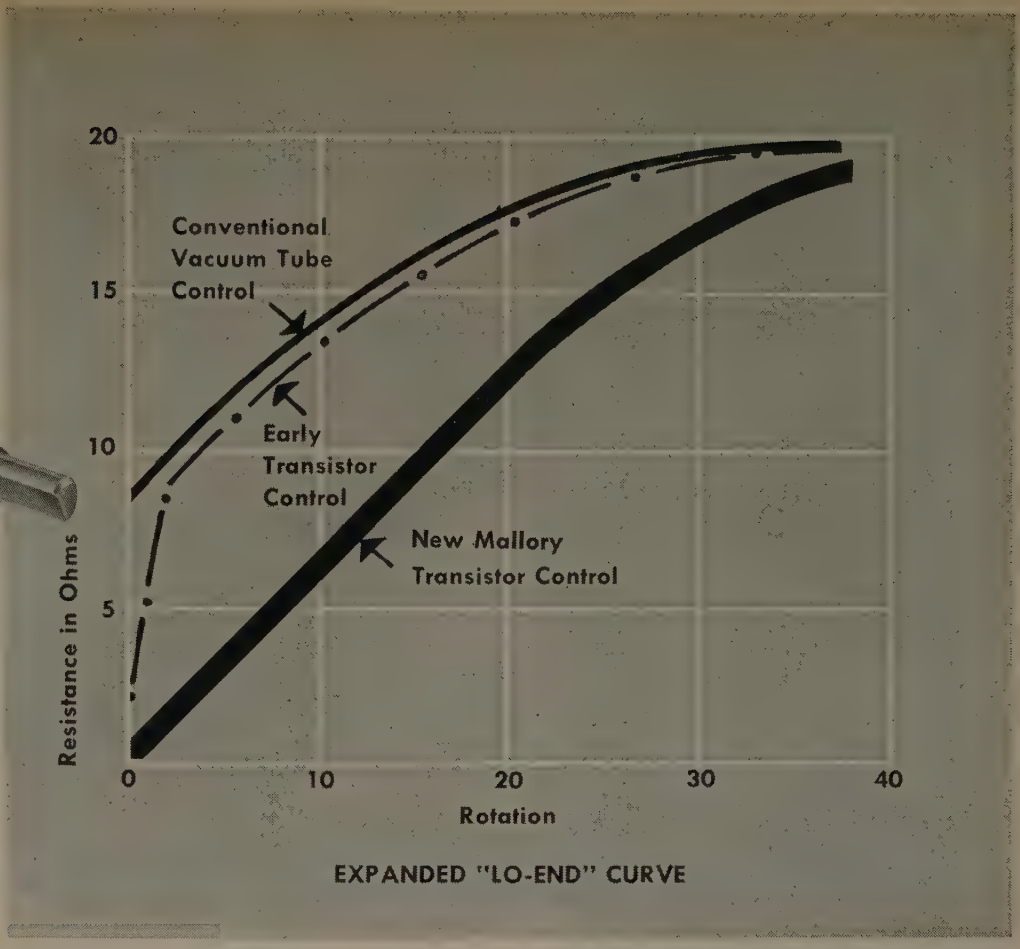
Hastings Raydist, Inc., Booth 3312
Engineering & Research Div.
Super H'way Pine Ave.
Hampton, Va.

▲ Charles E. Hastings, Raymond T. Doyle

Vacuum Controllers and Recorders. Transistorized Vacuum Gauges. Precision Air Velocity and Flow Measuring Instruments. Miniature Raydist Indicator for Electronic Tracking and Positioning.

(Continued on page 272A)





EXPANDED "LO-END" CURVE

Now...

A Control with Low-end Taper Especially Designed for Transistor Circuits

A new Mallory volume control, created specifically for use with transistors, provides characteristics not previously available to designers.

Low "hop-off" or zero rotation resistance
gives exceptionally low minimum volume level in low impedance circuits . . . permits full turn-down of volume level.

Special "low-end" taper
Starting from the "hop-off" value, resistance rises gradually through the first 20 to 30 degrees of rotation . . . thus providing smooth control of transistor circuit volume throughout the entire volume range.

Printed circuit design
Several models of the new control are available for use in printed circuits, for mounting vertical to or horizontal to the printed circuit panel.

Push-pull switch*
Available on all models . . . new Mallory push-pull line switch. Conventional rotary action switches can also be supplied with these new "low-end" taper controls.

Each sample control is supplied with a tag on which are given its overall resistance-rotation curve, plus a new "low-end" curve showing detailed resistance characteristics in the minimum volume range. Write to Mallory today for a sample in the resistance value, taper and mounting arrangement that you are considering for new designs . . . and for a consultation by Mallory control specialists on your particular requirements.

Expect more . . . get more from

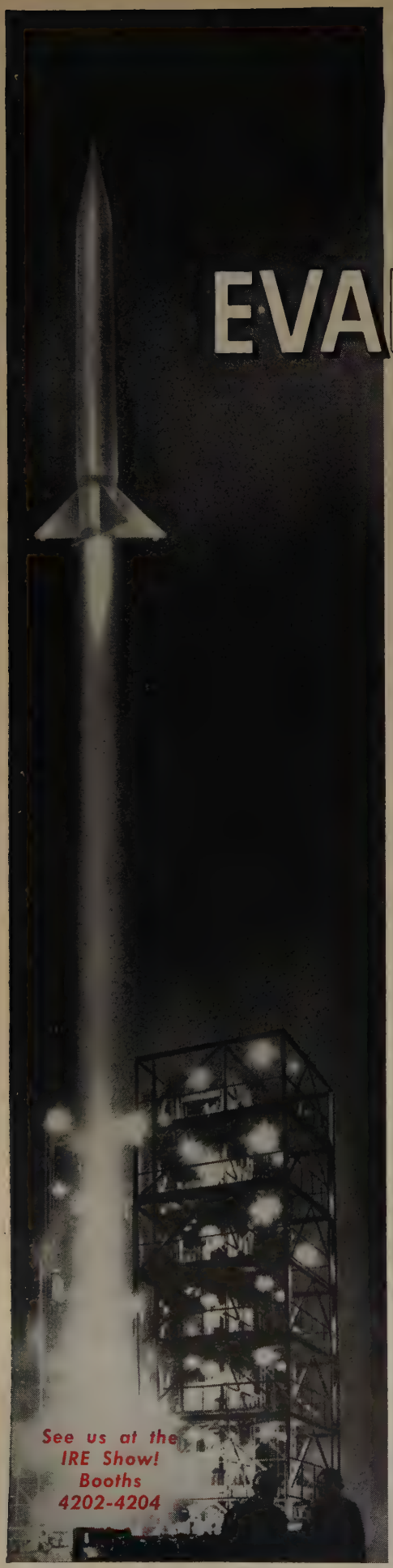
Serving Industry with These Products:

Electromechanical — Resistors • Switches • Tuning Devices • Vibrators
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Parts distributors in all major cities stock Mallory standard components for your convenience.

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P. R. MALLORY & CO. Inc.
MALLORY
P. R. MALLORY & CO. Inc., INDIANAPOLIS 6, INDIANA



All the unusual qualities required by precision equipment

—and more!

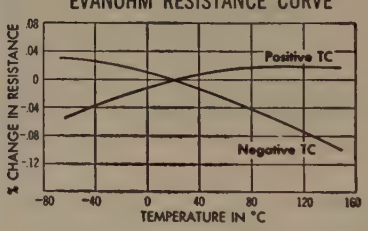
EVANOHM*

RESISTANCE WIRE

- FOR HIGH SPECIFIC RESISTANCE
- LOW TEMPERATURE COEFFICIENT AND LOW THERMAL EMF TO COPPER
- GREAT STABILITY OVER WIDE TEMPERATURE RANGES

EVANOHM is recommended for all precision applications where complete dependability over a wide temperature range is essential. It is especially well suited for aircraft instruments, guided missiles, rockets and other airborne equipment.

EVANOHM RESISTANCE CURVE



ANALYSIS — Ni 74.75%, Cr. 20.00%, Al 2.75%, Cu 2.50%

CORROSION RESISTANCE — Excellent

RESISTIVITY—800 ohms per circular mil foot (134 microhm cm.)

TEMPERATURE COEFFICIENT OF ELECTRICAL RESISTANCE — Plus or minus .00002 ohms max. per ohm per degree centigrade between —50°C. and +150°C.

THERMAL E.M.F. VS. COPPER—.0025 mv. per deg. between —50° and +105°C. (max.)

NON-MAGNETIC

HIGH TENSILE STRENGTH IN FINE SIZES — 150,000 to 200,000 p.s.i.

WORKABILITY—May be readily welded or brazed and soft soldered with special care.

AVAILABLE IN: (A) Bare wire .0005 and heavier. (B) Enamelled .0179 and finer. (C) Formex .0008 to .0113. (D) Silk, cotton, nylon and glass .0179 to .0015.

EVANOHM*

a patented, exclusive alloy produced by

WILBUR B. DRIVER CO.

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*Registered Trade Name

Whom and What to See at the Radio Engineering Show

(Continued from page 270A)

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Hamilton Watch Company, Booth 3120
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ELECTRONIC DAILY news magazine published during IRE Show and Convention on a daily basis. Will have their working editorial force operating at the booth. Also ELECTRONIC DESIGN and ELECTRONIC WEEK.

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Sub-Miniature timing devices and AC and DC Timing Motors. Repeat Cycle Timer, Time Delay Relays, Elapsed Time Indicators, Stop Clocks, Intervalometers, Custom Designed Timing Devices.

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Precision machined parts. The latest in precision components for electronics—aeronautics—hydraulics.

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HEATHKIT PORTABLE TRANSISTOR RADIO and ENGINE IGNITION ANALYZER. This new Heath-kit model 0-11 'extra-duty' 5" oscilloscope kit is just one of the many money-saving test items to be displayed at the Heath Company booth.

(Continued on page 296A)

SCIENCE at RCA

STARTING SALARIES: NON-MANAGERIAL TO $15,000 . . . MANAGERIAL OPEN

FIELDS OF ENGINEERING ACTIVITY		MANAGERS	TYPE OF DEGREE AND YEARS OF EXPERIENCE PREFERRED											
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			0-2	2-3	4-15	0-2	2-3	4-15	1-2	2-3	4-15	1-2	2-3	4-15
• SYSTEMS (Integration of theory, equipments and environment to create and optimize major electronic concepts.)	AVIATION ELECTRONICS • CONTROLS		W	W	W C	W	W	W C	W	W	W C			
	DIGITAL DATA HANDLING DEVICES	M C		M C	M C		C	C		C	C			
	MISSILE WEAPONS SYSTEMS • RADAR	M W	W	M W X C	M W X C	W	M W C	M W C	W C	M W X C	M W X C			
	INERTIAL NAVIGATION			W C	W C		W C	W C		W C	W C			
	COMMUNICATIONS		C	C N	C N	C	C				C N			
• DESIGN • DEVELOPMENT MISSILE WEAPONS SYSTEMS—Planning and Design--Radar—Fire Control—Servomechanisms—Computers		C M	W C M X	W C M X	W C M X	W C M	W C M	W C M X	W C M	W C M X	W C M X			
AVIATION ELECTRONICS—Radar—Computers—Servomechanisms—Shock and Vibration—Circuitry—Remote Control—Heat Transfer—Sub-Miniaturization—Automatic Flight—Automation—Transistorization—Infrared—Airborne TV		W C	W C X	W C X	W C X	W C	W C X	W C X	W C X	W C X	W C X			
RADAR—Circuitry—Antenna Design—Servo Systems—Gear Trains—Intricate Mechanisms—Fire Control—Information Handling—Displays		M C	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X			
COMPUTERS—Systems—Advanced Development—Circuitry—Assembly Design—Mechanisms—Programming—Digital Data Handling Devices		M	C W	M C X W	M C X W	C W	M C X W	M C X W	C W	M C W	M C W			
KINESCOPES (B & W and Color), OSCILLOSCOPES—Electron Optics—Instrumental Analysis—Solid States (Phosphors, High Temperature Phenomena, Photosensitive Materials and Glass to Metal Sealing)			L	L Y	L Y	L	L Y	L Y	L	L Y	L Y	L	L Y	L Y
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GAS, POWER AND PHOTO TUBES—Photosensitive Devices—Ceramic to Metal Sealing—UHF and VHF—Super Power			L	L	L	L	L	L	L	L	L	L	L	
COMMUNICATIONS—Specialized Systems—Microwave—Mobile—Aviation—Audio—Propagation Studies—Acoustics—Transducers			C N	C N	C N		C	C	C N	C N	C N			
BROADCAST AND TV—Monochrome and Color Studio Equipment—Cameras—Monitors—High Power Transmitters			C	C	C	C	C	C	C	C	C			
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MISSILE TEST INSTRUMENTATION (Data Acquisition and Processing)—Radar—Telemetry—Timing—Communications—Optics—Computers		F	F S	Z F S	Z F S	F S	F S	Z F S	F S	Z F S	Z F S			
RADAR—Airborne—Surface—Shipboard—Sonar—Fire Control		F	F S	Z F S	Z F S	F S	F S	Z F S	F S	Z F S	Z F S			
COMMUNICATIONS—Radio—HF—VHF—UHF—Microwave—Telephone—Teletype—Telegraph Terminal Equipment—Wave Propagation		F	F S	F S	F S	F S	F S	F S	F S	F S	F S			
• MACHINE DESIGN Mechanical and Electrical—Automatic or Semi-Automatic Machines			L H	L H	H	L	L H	H		L	L			

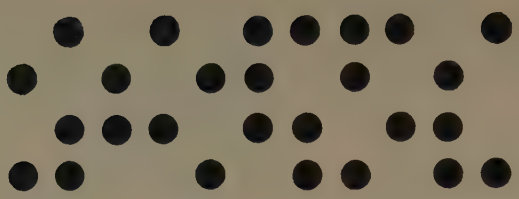
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Please send resume of education and experience, with location preferred, to:

Mr. John R. Weld, Employment Manager
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COMPUTERS

If you are an experienced computing analyst—or if computing and data reduction are new to you but you are a qualified engineer—there is interesting work as well as a bright future for you in Northrop Aircraft's growing Computer Center at Hawthorne, California.

Applied mathematicians and engineers are needed as computing analysts for assignment to Northrop's analogue computing facility, as well as the newly expanded digital electronic computer department which provides unparalleled service in the practical solution of complex engineering problems.

Northrop has many openings on its other projects having to do with jet aircraft and missile design. They include positions for electronics and electro-mechanical engineers and lab technicians. In addition to attractive compensation, Northrop offers benefits unexcelled in the airframe industry as well as helpful cooperation by forefront engineers for your professional advancement.

You'll like the comfortable working conditions, friendly people and modern equipment at Northrop. And you and your family will be living in Southern California where sea, mountains and desert offer year 'round recreation.

If you qualify for any phase of computer research, design or application, we invite you to contact the Manager of Engineering Industrial Relations, Northrop Aircraft, Inc., ORegon 8-9111, Extension 1893, or write to: 1015 East Broadway, Department 4600-U, Hawthorne, California.



NORTHROP

NORTHROP AIRCRAFT, INC., HAWTHORNE, CALIFORNIA

Producers of Scorpion F-89 Interceptors and Snark SM-62 Intercontinental Missiles

5-A-90



By Armed Forces Veterans

(Continued from page 292A)

SENIOR ELECTRONICS ENGINEER

MSEE. Age 34. Experienced digital techniques, transistorized circuits. Looking for growing company with as much faith in the future of data processing and computer field as I have. Single, can relocate or travel. Box 980 W.

INDUSTRIAL MGT. ENGINEER

MIE., BME., Tau Beta Pi, Pi Tau Sigma; age 34, married. 12 years' varied experience in electronics, project-methods, writing, teaching, radar mechanic, construction, sales. Prefer New York City vicinity, but would consider relocating. Box 981 W.

ENGINEERING EXECUTIVE

Young (under 35), dynamic, hard-hitting, Chief Engineer experienced in policy-making, organizing, staffing and running engineering activities. 10 years' commercial and military products background (including market evaluation) in test equipment, telemetry, and television systems. Seeking company which wants the job done, the right way, on time, every time, and will pay for such leadership. Long term association in Los Angeles greater area only. Resume upon request. Box 985 W.

ELECTRONIC ENGINEER

MSEE.; married; age 27. To be discharged August 1957. Have 2 years' experience with bombing and navigational systems, and while in the Service was concerned with this same phase. Also have 2 years' teaching experience at a midwestern university. Desires position in research and development field. Desires northeast location. Box 986 W.

ELECTRICAL ENGINEER

BSEE; married; age 35. 8 years' engineering experience. Communications engineering, antenna and microwave project engineer. Supervisory experience. Broad military experience. Desires position in small or medium company as sales engineer with future potential. Box 987 W.

Whom and What to See at the Radio Engineering Show

(Continued from page 272A)

Heinemann Electric Co., Booths 3811, 3813
610 Plum St.
Trenton 2, N. J.

Edgar Bromberg, ▲ Norman J. Schwartz, Richard S. Kurtz, Frank M. Ballou, Norman E. Taylor, B. A. Berlin

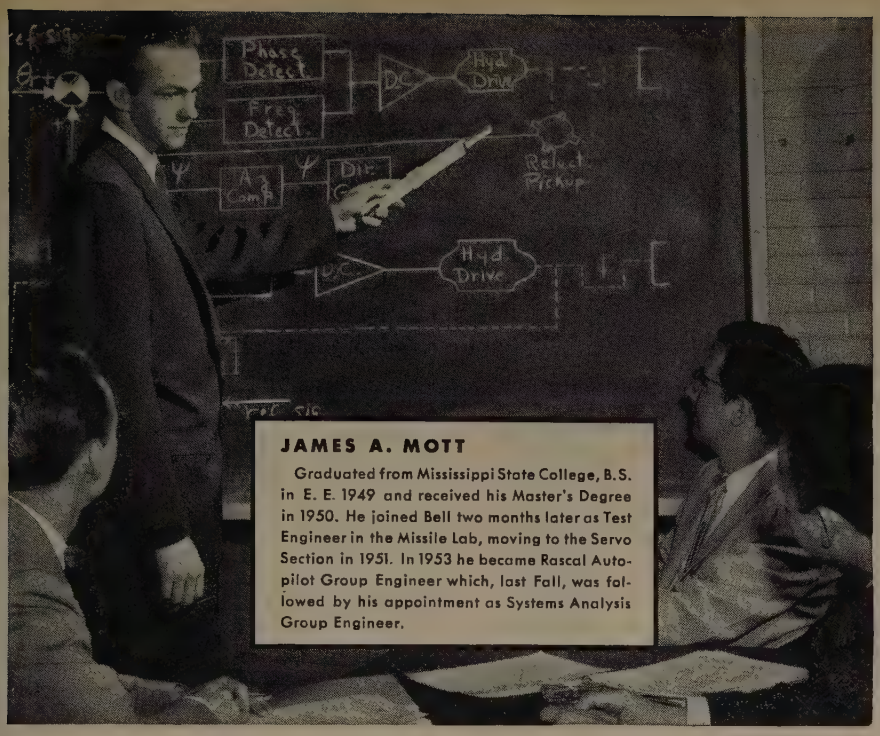
Exhibit features new circuit breakers and time-delay relays as well as operating panels demonstrating special circuit applications. Complete panorama will show circuit breakers from miniature to F-frame sizes.

Heldor Manufacturing Corp., Booth 4022
238 Lewis St.
Paterson, N. J.

Duke Ellington, Don Wilson, Abe Kalinsky, Ray Walker

Hermetically sealed bushings, terminals, fabricated transformer cans & covers.

(Continued on page 298A)



JAMES A. MOTT

Graduated from Mississippi State College, B.S. in E. E. 1949 and received his Master's Degree in 1950. He joined Bell two months later as Test Engineer in the Missile Lab, moving to the Servo Section in 1951. In 1953 he became Rascal Autopilot Group Engineer which, last Fall, was followed by his appointment as Systems Analysis Group Engineer.

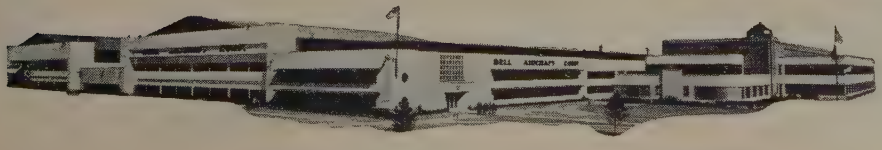
There are **NEW** Opportunities at BELL

James Mott is typical of the successful engineers who are now teamed together in Bell Aircraft's, newly-created Avionics Division with greatly expanded facilities and a building of its own. This recent divisional reorganization has created many top-flight openings for engineers and technicians and vastly broadened their opportunities for professional accomplishment. That fact, together with the number and wide diversity of Bell's projects, are insurance that your future at Bell will be limited only by your own capabilities.

You'll work in a fast moving, successful organization—in ideal surroundings with associates who have fine professional records. You'll have every opportunity to grow, learn and progress. Pay is high, benefits exceptional, and living conditions the best. If you're not moving fast enough or going far enough in your present position, contact Bell.

Write today: Manager, Technical Employment, Dept. 032, Weapon Systems Divison, **BELL AIRCRAFT CORPORATION, P. O. Box One, Buffalo 5, New York.**

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- Automatic Control Designers
- Chemical Engineers
- Combustion Research Engineers
- Communications Engineers
- Design Checkers
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- Digital Computer Development Engrs.
- Dynamic Engineers
- Electronic Engineers
- Electronic Standards Engineers
- Engineering Computers
- Environmental Specialists
- Field Test Engineers
- Flight Test Engineers
- Flight Test Programmers
- Fuel Injection Specialists
- Gear Designers
- Guidance Engineers
- Gyro Specialists
- Heat Transfer Engineers
- Hydraulic Engineers
- IBM Programmers
- Instrumentation Specialists
- Laboratory Test Engineers
- Magnetic Amplifier Specialists
- Mathematical Analysts
- Mechanical Engineers
- Microwave Engineers
- Miniturization Engineers
- Operations Analysts
- Physicists
- Power Plant Designers
- Pressure Vessel Designers
- Project Engineers
- Publication Engineers
- Radar Systems Engineers
- Rocket Test Engineers
- Servo Systems Engineers
- Servo Valve Engineers
- Statisticians
- Stress Engineers
- Structures Engineers
- Specification Writers
- Technical Writers
- Test Equipment Engineers
- Transformer Design Specialists
- Transistor Application Engineers
- Thermodynamic Engineers
- Telemetering Engineers
- Turbine Pump Designers
- Vibration & Flutter Analysts
- Weapons Systems Engineers
- Wave Guide Development Engineers
- Weights Engineers

TOP ENGINEERING POSITIONS

Norden-Ketay Corporation's management plan for 1957 provides for a further and continued emphasis on professionalism and creative ability.

Due to our immediate expansion plans our immediate needs are for the filling of several positions on the junior level as well as on the senior level.

The senior engineer is afforded the opportunity of full expression of engineering creativity as well as management direction.

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5 to 7 years experience in Rotating Components field. Supervisory experience essential. Will have responsibility of complete branch. Report directly to chief engineer.

SECTION HEAD SERVO MOTORS

3 to 5 years experience in design and development of torque type rotating components. (Servo motors, damps, blower motors.) Capacity to supervise engineers and technicians. Report directly to branch head.

RESOLVER DESIGN ENGINEER

Minimum of 1 year's experience in rotating components design.

SR. TRANSISTOR ENGINEER

To Head Up Electronic Amplifier Section

THERE ARE SEVERAL POSITIONS AVAILABLE FOR INTERMEDIATE & JUNIOR LEVELS IN THE ABOVE CATEGORIES.

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Designers, Detailers, Layout Men

Positions available for juniors as well as men with experience in precision electro-mechanical components, servos, synchros, gear trains and amplifiers. Ability to work with minimum of supervision preferable.

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PRECISION COMPONENTS DIVISION
BroadHollow Road & Allen Boulevard
Route #110 Farmingdale, L.I., N.Y.

Whom and What to See at the Radio Engineering Show

(Continued from page 296A)

Helipot Corporation, Booths 2602-2606
Div. of Beckman Instruments, Inc.
Newport Beach, Calif.

Potentiometers, delay lines, dials.

Heminway & Bartlett Mfg. Co., Booth 4105
500 Fifth Ave.
New York 36, N. Y.

C. Duane Houk, Harold Zettwoch, Walter Thompson, Edward Vogel, Jay Vine, Ary Lamme

See newest scientific Teflon-coated Fiberglas lacing tapes. Withstand temperatures up to 600°. Also nylon lacing cords and flat braided tapes that tie easier, faster, tighter!

Hermetic Seal Corporation
29-37 South Sixth St.
Newark 7, N.J.
Booth 3936

Leonard Box, Harold Hall, Jack Wolfkind, Irving Cooper, Al Karr, Royce Dunleavy

Recon plugs and midget AN connectors glass to metal seals including: transistor & diode housings, capacitor seals, crystal bases, feed thru and multi-headers.

Hertner Electric Co., Booths 1501-1509
Sub. General Precision
12690 Elmwood Ave.
Cleveland 11, Ohio

BLOWERS—CONVERTERS
MOTORS—SERVOMOTORS

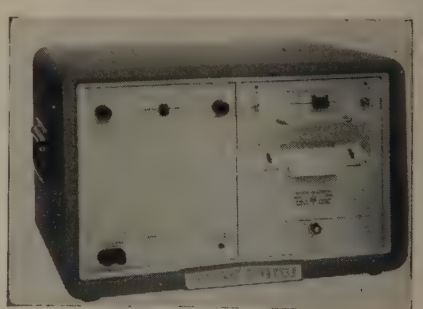
Hetherington, Inc., Booth 2337
1200 Elmwood Avenue
Sharon Hill, Pa.

Julius Uradnisheck, Edward Kaufholz, Fred Mitchell, George E. Maher, Merrill F. Sproul, Vern Kline, S. Richard Haws, Mat Kronstadt, Joseph H. Schellman

* Combined Switch and indicator light with two-color lens, for computer panels. New keyboard type computer switch. Wide variety switches, indicator lights, and relays.

Hewlett-Packard Co.
275 Page Mill Rd., Palo Alto, Calif.
Booths 2509, 2513

▲ William R. Hewlett, ▲ David Packard, ▲ Bernard Oliver, ▲ W. Noel Eldred, ▲ Cortlandt Van Rensselaer, William P. Doolittle



Digital Recorder Model 560A

Model 130AR Rack Mounted Oscilloscope.
Model 207A Audio Sweep Oscillator—For rapid audio tests.
Model 560A Digital Recorder—Provides continuous record for Frequency Counters.
Model 686A Backward Wave Oscillator—Provides electronically swept frequencies for microwave testing.

(Continued on page 301A)

Whom and What to See at the Radio Engineering Show

(Continued from page 298A)

Hickok Electrical Instrument Co.
10514 Dupont Ave.
Cleveland 8, Ohio
Booths 3516-3518

R. E. Hickok, H. D. Johnson, J. H. Sonneborn, K. E. Hughes, R. K. Arbogast, N. J. Laub, J. L. Walls

Automation-type electronic test equipment includes new Cardmatic tube tester, burn-out-proof multimeter, balancing equipment, stroboscopic equipment, cathode ray oscilloscopes, signal generators and a complete line of electronic testing equipment.

Hi-G Inc., Booth 2114
Bradley Field
Windsor Locks, Conn.

▲ Robert H. Wood, A. Lokash, S. Pelgar, ▲ G. Podeyn, ▲ S. Schmidt

The Newest versions of Sub-miniature AC Relays for Critical Aircraft & Missile applications along with improved sub-miniature DS relays for all applications.

Hill Electronic Eng. & Mfg. Co., Inc.
New Kingstown, Pa.
Booth 1617

▲ B. C. Hill, Jr., ▲ R. W. Tinkham, ▲ Ray Green, ▲ G. R. Houck, R. H. Van Zandt, R. J. Middleton

Miniaturized Frequency Control Devices—Printed Circuit Reliability—Crystal Controlled Accuracy at Sub Audio to Radio Frequencies—Crystals from 400 CPS to 500 Kc and Crystal Filters.

Hitemp Wires, Inc.
26 Windsor Avenue
Mineola, Long Island, New York
Booth 4229

George D. Newman, ▲ John W. Holland, Michael Zangrillo, Hector Hayden, Robert Colucci, William Frogner

Hitemp's new high strength teflon lead wire achieves a 2% increase of tensile strength in fine teflon hook-up wires with no appreciable difference in electrical properties. A new ink which retains all properties of teflon for printing of numerals etc., on teflon insulated wires.

Hoffman Electronics Corp.
Hoffman Semiconductor Division
930 Pitner Ave., Evanston, Ill.
Booth 3830

R. Herter, D. Dickson, Henry Schoemehl, B. Ross, M. Prince, J. Madigan, A. Ertell, E. Gould

Hoffman

Hoffman Semiconductor "Blue Chip" Silicon junction products ranging from subminiature axial glass diodes to ultra-stable Zener reference elements and fifty ampere, 400 volt rectifiers.

Honeycomb Co. of America, Inc., Booth 4408
3 Burroughs St.
Bridgeport 8, Conn.

Jim Wheeler, Frank Quinlan, Irv Horine, Dan Judge Sr., Dan Judge Jr., Don Smiley, Phil Williams

Quality Fabricators of radomes, Fiberglas tubing, low pressure laminates, to MIL 8013 A and 9041 A.—Honeycomb mounting plates, for light weight, high strength, high rigidity applications.

(Continued on page 302A)

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Whom and What to See at the Radio Engineering Show

(Continued from page 301A)

Houghton Laboratories, Inc., Booth 4237
322 Houghton Ave.
Olean, N. Y.

▲ William C. Jenner, R. M. Houghton, John M. Jewell, Donald Roon, Walter S. Thorpe

Announcing the HYSOL 6900 product series, entirely new, resilient to flexible epoxys, combining long pot life with rapid cure. They are economical and stable, of a long time-temperature range.

Harvey Hubbell, Inc., Booth 3832
State St. & Bostwick Ave.
Bridgeport 2, Conn.

Harold D. Long, W. C. McClane, J. F. Healy, M. C. Piombo

Interlock electronic connectors. Miniature and sub-miniature jacks and plugs, single wire. Cold headed machine screws, wiring devices.

Hudson Tool & Die Co., Inc.
18 Malvern Street
Newark 5, New Jersey
Booths 4106-4108

E. Isler

Precision drawn instrument cases & covers.

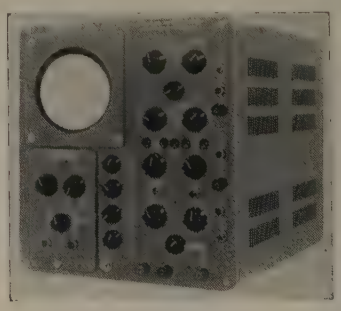
Huggins Laboratories, Inc.
711 Hamilton Avenue
Menlo Park, California
Booths 3927-3929

▲ R. A. Huggins, ▲ L. A. Roberts, ▲ V. W. Christensen

Forward Wave Amplifiers. Backward Wave Oscillators. Backward Wave Amplifiers. Associated Solenoids. Periodically Focused Traveling Wave Tubes.

Hughes Aircraft Company
Florence & Teale Streets
Culver City, Calif.
Booths 2801-2805

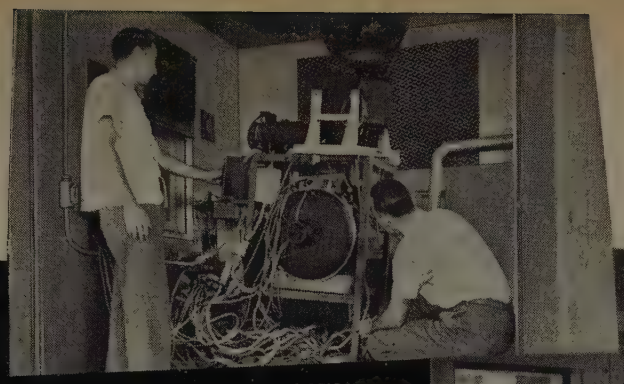
J. Hurley, W. Gray, H. K. Mann, ▲ E. L. Michaels, ▲ W. J. Cronin, P. Phol, A. E. Fisher, B. A. Coler, ▲ J. C. Bailey, R. H. Budd, D. W. Harr, ▲ F. Avery



Model 104 Memo-Scope

*Memo-scope 104, *Silicon Power Rectifiers, *Quick Recovery Diodes, Slow-Scan Television Demonstration, Typotron—Character Display Storage Tube, Transistors, Armament Control System Components, Falcon Missile.

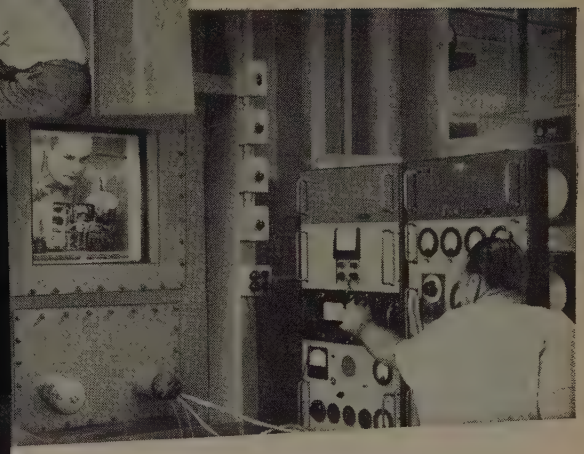
(Continued on page 304A)



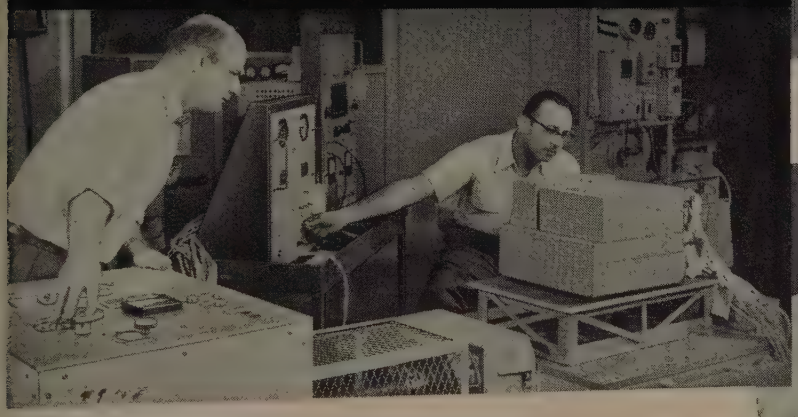
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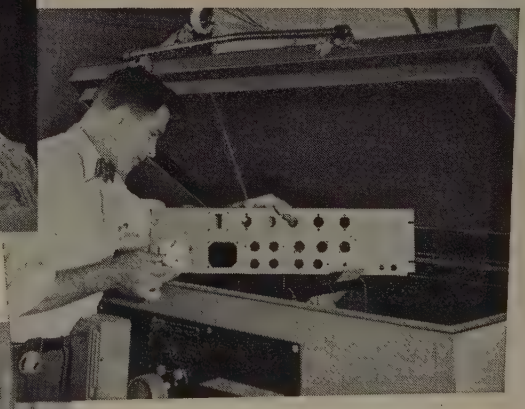
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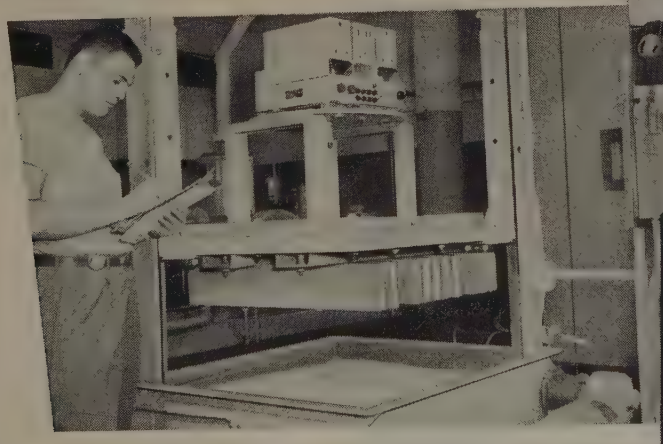
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B.S. M.S. Ph.D.

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SOLID STATE

AEW (air-borne early warning)

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RESEARCH AND DEVELOPMENT

MIT

LINCOLN LABORATORY

BOX 16

LEXINGTON 73, MASS.

Whom and What to See at the Radio Engineering Show

(Continued from page 302A)

Hull Corporation, Booth 4114
1941 Woodland Road
Abington, Pennsylvania

Lewis W. Hull, John L. Hull, Frank N. Cramton, John H. Leary, Joseph Piotrowski, MacLean Brown, John Smith

The first fully automatic transfer molding press designed especially for electronic parts. Also a special high vacuum impregnating system for the Electronic Industry.

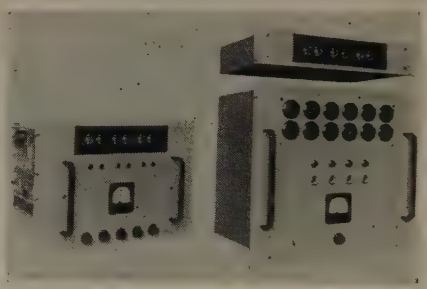
Hupp Electronics Co., Booth 2631
743 Circle Avenue
Forest Park, Ill.

Marvin Lubin, T. A. McCollum, C. N. Pederson, ▲ W. Samuelson, ▲ Herman Shall, ▲ D. V. Sinninger

See a half-watt photocell—a remote control system with 1000 different codes—digit-table, a high visibility numerical readout—quartz crystals with a new standard of accuracy.

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75 Cambridge Parkway
Cambridge 42, Mass.
Booths 3038-3039

John Memishiam



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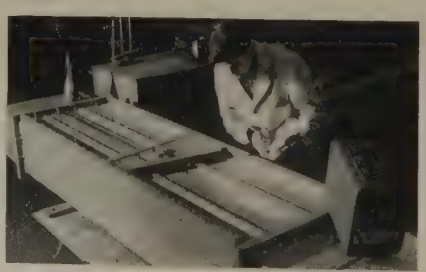
Hycon Mfg. Co., Booth 3037
2961 E. Colorado St.
Pasadena 8, Calif.

Don Downie

Oscilloscope, VTVM, Digital VTVM with printout, rack mounted electronic test equipment, Electronic Camera, Control systems.

I-T-E Circuit Breaker Co.
19th & Hamilton Streets
Philadelphia 30, Pa.
Booths 1313-1315

▲ Samuel King, ▲ Marvin Feller, Paul Garrison, ▲ David Bowman, ▲ Frank Gardiner, Jerome Corwin



Slotted Line for Waveguide Size WR-2100

Large Waveguide, WR-770 through WR-2300 and component test equipment; slotted lines; directional couplers; waveguide leads; attenuators; waveguide-coax transitions; short-circuit plungers. Many waveguide sizes and configurations. Radar antenna and microwave communication systems.

(Continued on page 305A)

Electrical & Electronic

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How to get the most out of Life and your Engineering Talent

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Engineering and Scientific Personnel

GOODYEAR AIRCRAFT

LITCHFIELD PARK, PHOENIX, ARIZONA

Similar opportunities available in our Akron, Ohio Laboratory

Whom and What to See at the Radio Engineering Show

(Continued from page 304A)

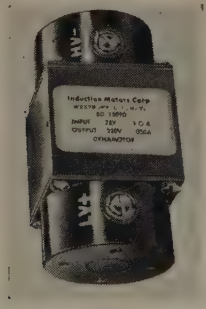
Ideal Industries, Inc. Booth 4030
Sycamore, Ill.
C. J. Boehmer, J. W. Richardson, A. W. Simmill, R. D. Paul, A. C. Romero, A. Carideo
Strip all types of film insulation from #25 to 50 wires with "twin-cone" fibre glass wheels, strip faster, closer without damage to fine wires.

Illinois Condenser, Booth 2314
1616 N. Throop St.
Chicago 22, Ill.
▲ Joseph J. Kurland, ▲ Jerome Kurland, L. W. Coleman
SMT (Subminiature capacitors)

Illinois Tool Works, Shakeproof Division, Booths 4231-4233
St. Charles Road
Elgin, Illinois
R. D. Toler
*Industrial fasteners by Shakeproof for Radio-TV industry.
*Model automatic power screw driver.
*LICON precision switches.
Products and services of new FASTEX division.

The Indiana Steel Products Co., Booths 2432-2434
Valparaiso, Indiana
C. A. Maynard, I. A. Dickey, P. M. Wheeler, K. S. Talbot, V. Farr, R. Hurley, R. P. Janes
*High energy Ceramic Permanent Magnet—Indox V—will be featured. All grades of Alnico Magnets also displayed and Magnet Design consultation on visitors' problems is offered.

Induction Motors Corp.
570 Main St., Westbury, L. I., N. Y.
Booth 2229
S. Saretzky, J. Wohryzek, A. J. Silverman, A. H. Mankin, M. Hayden, G. Egan, R. W. Kopprasch, C. Burmeister, H. Fried



Model BD-1509D Dynamotor for Guided Missiles & Telemetering

Dynamotors; synchros, resolvers and solenoids; servo, gear, blower, actuator motors; synchronous and non-synchronous in ratings from 1/1000 to 1/4 horsepower.

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Robbins Lane
Syosset, L. I., N. Y.
C. Cherry, J. Waddell, ▲ A. Freed, ▲ M. Chaffee
High-speed motion analysis cameras; oscilloscope recording cameras; radar moving target simulator.

(Continued on page 306A)

* Indicates new product.
▲ Indicates IRE member.

Be sure to bring your registration card with you. It identifies you as an IRE member for fast registration.

ELECTRONIC ENGINEERS

CHALLENGING OPPORTUNITIES

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- RADAR
- COMMUNICATIONS
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. . . enjoy working in a modern new 70,000 square foot building . . . another building of same size is now under construction.

. . . drive just 45 minutes to New York City and only one hour to the Jersey Shore, mountains and lakes in N.J. and Pennsylvania.

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STAVID also offers challenging permanent field assignments at more than 30 desirable locations, throughout the U.S. for those engineers interested in a location other than New Jersey.

DURING IRE CONVENTION

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At the Mayflower Hotel, 15 Central Park West
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COlumbus 5-0060

or send resume to:

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See Mr. Montgomery at the Waldorf-Astoria during the I. R. E. Convention.

MARTIN

BALTIMORE

Whom and What to See at the Radio Engineering Show

(Continued from page 305A)

Industrial Hardware Mfg. Co., Inc.
109 Prince St.
New York 12, N. Y.
Booth 2715

Martin Cohen, John Donato

Printed circuit sockets, transistor and subminiature sockets, laminated sockets, terminal strips, anode connectors, wired assemblies, metal and bakelite stampings.

Industrial Instruments, Inc.
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Cedar Grove, N. J.
Booths 3017-3018

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*Low priced component testers, eliminate operator decision, are fast and accurate. *High current, high potential testers, megohmmeters, ohmmeters, wheatstone bridges.

Industrial Laboratories Publishing Co., Booth 4225
201 North Wells St.
Chicago 6, Illinois

Publishers "Industrial Laboratories" Magazine.

Industrial Products Co., Booths 2517-2519
Div. of Danbury-Knudsen, Inc.
P. O. Box 148
Danbury, Conn.

Frank Knudsen, Myron Rose, Reynolds Fowler, Warren Loughlin, ▲ Carl Concelman

Miniature coax connectors & switches*, UG connectors—printed circuit coax connectors, 6-12 position coax switches*, rack & panel connectors.

Industrial Test Equipment Company
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Booth 3229

Raymond Rothschild, Melvin Schreibman



Model 200A Phase Meter

*Phase Meters, Null Meters, Impedance Comparators, Power Oscillators, Frequency Standards, Automatic HiPots, and other electronic equipment.

Industrial Timer Corporation, Booths 2211-2213
1407 McCarter Highway
Newark 4, New Jersey

M. A. Brauner, F. G. Corbutt, K. P. Kraemer, R. A. Rossney, Bernard Volin

(*Modular line of punched card programming equipment.) Synchronous motor driven recycling timers, percentage timers, multi cam timers.

(Continued on page 309A)

* Indicates new product.
▲ Indicates IRE member.

I·R·E
NATIONAL CONVENTION AND RADIO SHOW

Significant developments at Lockheed Missile Systems Division have created new openings for:

Controls Systems Engineers—to analyze and synthesize complex automatic control systems.

Inertial Guidance Engineers—to perform systems analysis and design of inertial guidance systems.

Infrared Specialists—to perform preliminary systems design and parametric optimization of advanced infrared detection systems.

Data Processing Systems Specialists—to perform advanced system development and design in new techniques of automatic data processing.

Weapons Systems Specialists—to perform basic analysis and systems evaluation of advanced weapons systems.

Electronic Product Engineers—to translate laboratory electronic systems into prototype models meeting the rigid requirements of modern weapons systems.

Radar Systems Engineers—to develop advanced radar systems associated with guided missiles.

Theoretical Physicists—to analyze propagation of electromagnetic waves through the ionosphere and through dielectric materials and study radiation problems pertaining to advanced antennas in the microwave and millimeter domain, including scattering problems related to the reflection of electromagnetic waves from simple and complex boundaries.

Experimental Physicists—to investigate microwave circuit components including ferrites and various millimeter wave techniques such as MAZUR.

Antenna Specialists—to design and develop airborne antennas and radomes for high speed missiles for telemetering, radar, and guidance systems application.

Video Specialists—to develop advanced systems for the transmission of visual data by electronic means.

Circuit Design Specialists—to design telemetering and guidance systems utilizing advanced circuit components.

Positions are open at the Palo Alto Research Center and Sunnyvale and Van Nuys Engineering Centers. M. H. Hodge, M. W. Peterson and senior members of the technical staff will be available for consultation at the convention hotel. Phone PLaza 14860 or 14861.

Lockheed

MISSILE SYSTEMS DIVISION

Whom and What to See at the Radio Engineering Show

(Continued from page 306A)

Industrial Transformer Corp., Booth 2112
Gouldsboro, Pa.
Dale Ander, Sam Lundy
Custom transformers to military and commercial specifications. Incremental Inductance Bridges and Insulation Breakdown Testers.

Industrial Winding Machinery Co.
120 Wall St., New York 5, N. Y.
Booth 4405
R. Roehrig, Leslie Stallard
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Institute of Radio Engineers
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Instrument Specialties Co., Inc.
244 Bergen Blvd.
Little Falls, N. J.
Booth 4320
J. D. Roberson, J. H. Baker, A. W. Ullmann, F. S. Stickney
Beryllium Copper Products. Electronic Components. Standard high frequency contact finger strips and rings. Custom made beryllium copper coil and flat springs, screw machine products.

Instruments for Industry, Inc.
150 Glen Cove Road
Mineola, L. I., N. Y.
Booth 2830
▲ E. B. Novikoff, ▲ F. S. Macklem, ▲ I. Goodman, ▲ E. Seabury, ▲ M. Freiser, ▲ L. I. Algase
Model M-395 Wide Band Amplifier. The Super Video Amplifier is designed to provide an extremely broad bandpass of 1000 cps to 50 mc coupled with a gain of 70db.

(Continued on page 312A)

Lunch counters are located on each floor of the Coliseum building, and a cafeteria is on the second floor mezzanine. There are also several good restaurants in the immediate neighborhood.

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Military and Civilian

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TUNER ENGINEER
To design tuners for UHF and VHF systems—military and civilian. To pursue a program of original ideas in this field at the developmental level.

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With experience in designing horizontal and vertical oscillators, control circuits and associated components.

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TV receiver engineer for work on a line of export receivers. Familiarity with tuners and I.F. systems for European standards and conditions useful in this work. Will consider a non-citizen with practical TV experience.

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No blue sky...just

to back up our belief that

you and Collins

We're going to build a proposition which we believe deserves your most serious consideration, if you are a mechanical or electrical engineer. This proposition is built on pure and simple fact—no high flown promises or broad generalities. Our proposition: you and Collins should get together. We present these facts to support it.

FACT NUMBER 1:
Collins Radio Company's sales have increased 10 fold in each of three successive seven year periods. 1953 sales were $100,000; 1940 sales, $1,000,000; 1947 sales, $10,000,000; 1954 sales, $100,000,000, and 1956 sales, $126,000,000. (Note graph.) This company *has grown, and is growing* at a phenomenal rate. Total employment is 9,000 of which 24% are research and development personnel.

You grow when the company you work for grows.

FACT NUMBER 2:
As shown in the graph at right, the employment of research and development personnel has increased steadily despite fluctuation in sales. Notice that even during periods of national sales regression Collins continued to strengthen its engineering staff.

Collins has based its growth on the solid foundation of stability in the engineering department.

FACT NUMBER 3:
At Collins, the ratio of engineers to total employees is extremely high, far higher than the average among established companies engaged in both development and production. First and foremost, Collins is an engineering company.

Engineering is king at Collins—never takes a back seat to production expediency.

FACT NUMBER 4:
Collins' reputation for quality of product is universally recognized. It has led to Collins' phenomenal sales record. At Collins there is no compromise when quality is at stake.

If you're the man we want, you'll get real satisfaction out of this quality-consciousness.

FACT NUMBER 5:
Electronics is Collins' only interest. In no way is it subsidiary to the manufacture of industrial or consumer products. Collins builds electronic equipment, not airplanes or vacuum cleaners. Every research, development and production facility is devoted to progress in electronics.

If electronics is your interest, you'll like the climate at Collins.

FACT NUMBER 6:
There is a limitless variety of fields and types of work for the Collins engineer. Recent Collins work in air and ground communication, and aviation electronics include developments in transhorizon "scatter" propagation; single sideband; microwave and multiplex systems; aircraft proximity warning indicator; aviation navigation, communication and flight control; broadcast; and amateur equipment.

There is big opportunity for your special talents.

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You will work in one of Collins' new research and development laboratories located at Cedar Rapids, Iowa; Dallas, Texas; and Burbank, California. Offices and subsidiary companies are located in New York; Washington, D. C.; Miami; Knoxville; Seattle; Hickman Mills, Missouri; Toronto, Canada; London, England; and South America.

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We repeat—if you are a mechanical or electrical engineer, you and Collins should get together. Take the first step now, send your resume today to:

L. R. Nuss
Collins Radio Co.
Cedar Rapids,
Iowa

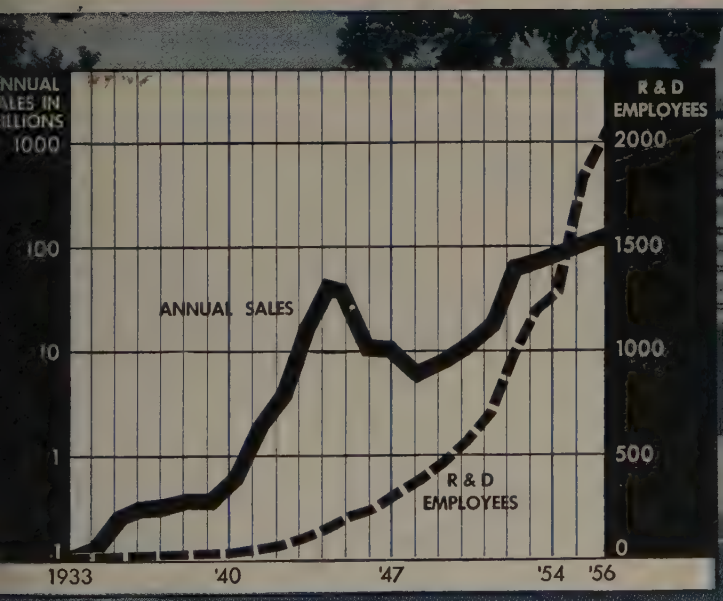
Fred Aiken
Collins Radio Co.
2700 W. Olive Ave.
Burbank, California

Harold McDaniel
Collins Radio Co.
1930 Hi-Line Drive
Dallas, Texas



black and white facts should get together

Collins will be interviewing engineers and tech writers during the IRE Show in New York March 18-22. Call L. R. Nuss, CIrcle 5-7076, for a personal, confidential interview.



This graph shows the relationship between sales and employment of engineering personnel at Collins. Notice the steady increase in research and development employment despite sales fluctuations.



Collins new research laboratory building at Cedar Rapids, Iowa. Air-conditioned, shielded against radio waves, completely equipped.

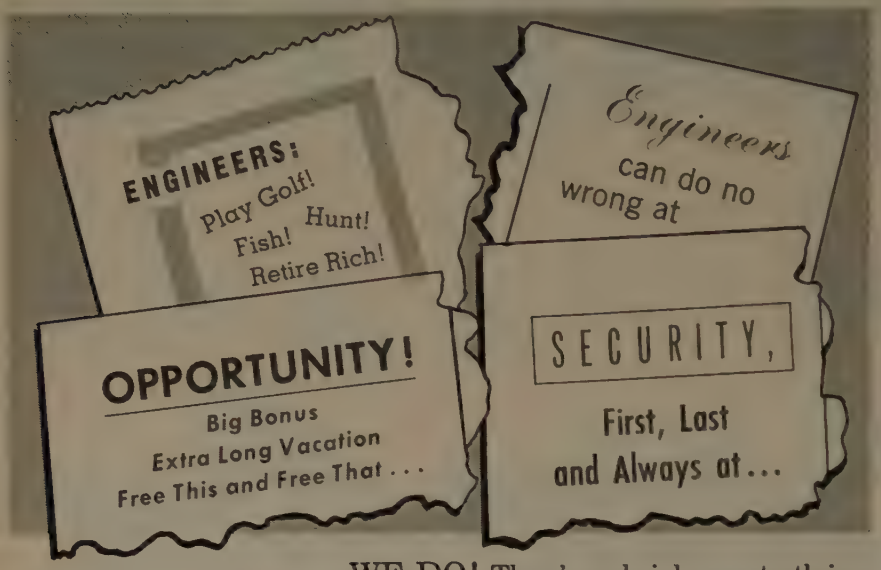
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Degree.....College.....

Whom and What to See at the Radio Engineering Show

(Continued from page 309A)

Instruments Publishing Co., Inc., Booth 3019
845 Ridge Ave.
Pittsburgh 12, Pa.

Richard Rimbach, Sr., Richard Rimbach, Jr., Martha Rimbach, Gretchen Rimbach, Milton Aronson, Claude Morrison, Fred Marton, David Aland, James Emge, Robert Nelson, C. F. Goldcamp

Military Automation—a *publication, which will appeal particularly to those who design, specify and apply electronic and control equipment and components for communications, radar, sonar, fire control, aircraft, missiles, rockets, etc.

Insuline Corp. of America, Booth 4318
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Manchester, N. H.

▲ B. L. Cahn, ▲ M. S. Spector, ▲ W. J. Schoenberger, H. Weston, J. Finkle

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International Business Machines Corp.
590 Madison Avenue
New York 22, New York
Booths 1801-1805

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International Electronic Research Corp.
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International Electronics Corp., Booth 2002 (Great Britain Room)
81 Spring St.
New York 12, N. Y.

B. B. Grossman, M. Grossman, E. J. Porto, I. Friedman

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International Instruments, Inc., Booth 2814
P. O. Box 2954
New Haven 15, Conn.

R. C. Livingston, John E. Hines, Jack Conn

Side Indicator Panel Meters, Miniature Rotary Switches.

(Continued on page 314A)

Leadership in Action EBWR

TYPE: Experimental boiling water reactor—designed and built by the Argonne National Laboratory.

POWER: 5000 kilowatts of electrical power capable of supplying most of the Laboratory's requirements.

SIGNIFICANCE: The first of five prototype reactors completed under the AEC developmental program of atomic power for civilian use.

STATUS: Brought to full power in December, 1956.

Argonne
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Operated by the University of Chicago under a contract with the United States Atomic Energy Commission

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Outstanding high level positions for engineers with telephone company experience in toll transmission.

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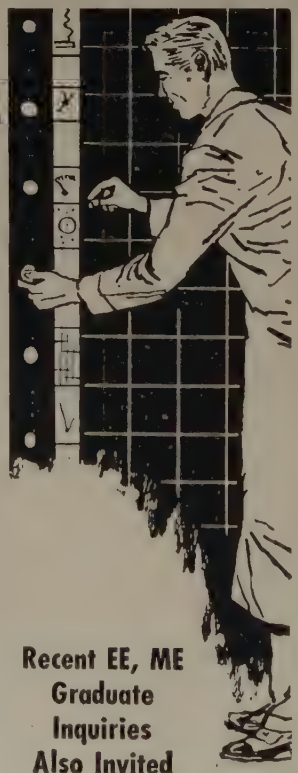
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GENERAL MOTORS CORPORATION
FLINT 2, MICH. • MILWAUKEE 2, WIS.

Whom and What to See at the Radio Engineering Show

(Continued from page 312A)

International Nickel Co., Inc., Booths 2722-2728
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New York 5, N. Y.
H. J. Thompson, S. Spoor, G. R. Anner, C. W. Hudson
Uses of nickel and high alloys in electronics ultrasonics, and lighting with emphasis on new developments made possible through "Nickel . . . The First Metal in Practical Electronics."

International Pump & Machine Works, Inc., Booth 4505
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Livingston, N. J.
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Small portable impregnating units.

International Radiant Corp.
4 Manhasset Ave.
Port Washington, L. I., N. Y.
Booth 1225
Albert J. Deeb
Environmental Temperature Chambers. Member of Environmental Equipment Institute.

(Continued on page 316A)

* Indicates new product.
▲ Indicates IRE member.



"NIGHT CHESS" a painting by Simpson-Middleman, a doubly gifted team of artists with a scientist's penetrating insight. They portray here "a chess-like game played in a segment of space on a skewed board with pieces of uncertain value against an unknown antagonist. The next move is unforeseen—it will come out of the dark—it will be history's most fateful gambit."

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It is a stimulating experience. And in this sympathetic climate, you'll find very quickly that "you belong . . . at Boeing."

Drop a note now to John C. Sanders, Engineering Personnel Administrator, Boeing Airplane Company, Department G-61, Seattle 24, Washington.

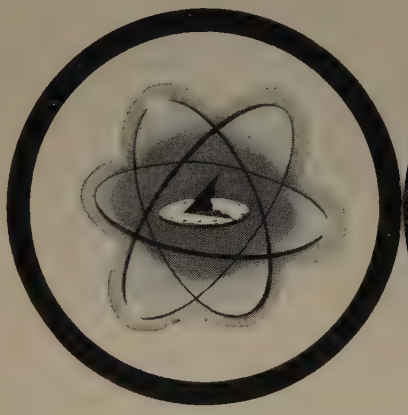
BOEING

engineers and scientists

NATIONAL IS LOOKING FOR THE UNCOMMON MAN

...because it takes a man of uncommon imagination and skill to solve the knotty problems we face in the fields of radar, communications and navigation.

This is the sort of engineer and scientist who has been pioneering new products in new areas for National right along.



One of our recent "firsts" is the ATOMICHRON,* National's cesium beam "atomic clock," a frequency producing instrument for electronic research and development, offering a degree of accuracy and stability never before attained.

This remarkable instrument is an important step forward in the solution of today's increasingly intricate communications and navigation problems. Technical applications open to the Atomichron include radio and TV transmission, marine and airborne navigation, standard timers and many other areas.

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If you are this type of engineer—investigate the opportunities National has for you—in the fields of:

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• Vibration and Shock • RF Circuits (110 kc to 10,000 mc)

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Mr. John A. Bigelow

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"Leader in quality electronics for over 40 years"

**A precision frequency standard using new techniques capable of stabilities to 1 part in 10¹¹.*

Whom and What to See at the Radio Engineering Show

(Continued from page 314A)

International Rectifier Corp.
1521 East Grand Ave.
El Segundo, Calif.
Booths 3806, 3808



DeForest Audion Tubes & Detectors

"Cavalcade of Electronics"—Rare and Historical Electronic Devices—Early TV Tubes—Edison Tubes—One of Marconi's First Detectors—DeForest's Audion Tube—Plus Latest Advances in Recifiers—Selenium—Germanium—Silicon

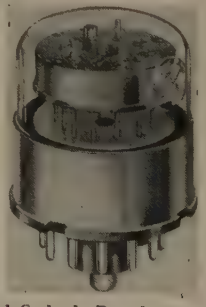
International Resistance Co.
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Philadelphia 8, Pa.
Booths 2821-2825

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International Standard Trading Corp.
22 Thames Street, New York 6, N. Y.
Booth 2008 (Great Britain Room)

J. T. Benjamin, F. W. Warden, ▲ D. D. Bulkley, J. B. Rafferty, L. Milano



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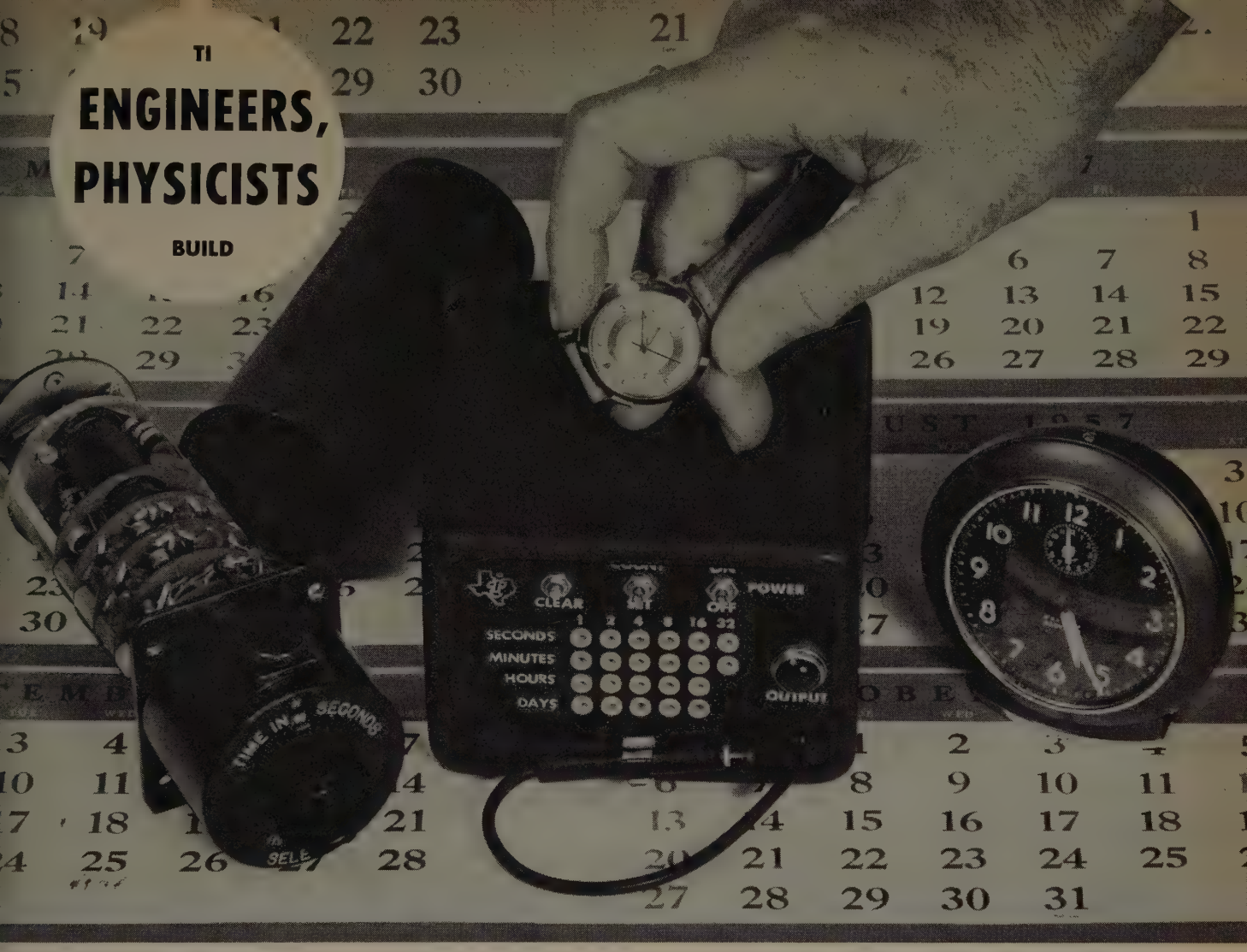
International Telemeter Corp., Booth 4428
Ampli-Vision Div.
2000 Stoner Ave.
Los Angeles 25, Calif.

V. G. Rumbellow, M. Jungman

Semi-rigid helical membrane aluminum sheathed coaxial cables, sizes ½" to 3⅛", complete with fittings. Polyethylene dielectric for normal use; Teflon dielectric for higher temperatures.

(Continued on page 318A)

* Indicates new product.
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ELECTRONIC & ELECTROMECHANICAL APPARATUS — Radar, sonar, infrared, navigation, magnetics, telemetering, communications, computers. *Write R. E. Houston.*

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Employment Manager, Dept. I

AVCO Manufacturing Corp.
Crosley Division
2630 Glendale-Milford Road
Evendale, Cincinnati 15, Ohio

Whom and What to See at the Radio Engineering Show

(Continued from page 316A)

J-B-T Instruments, Inc., Booth 2734
441 Chapel Street
New Haven 8, Conn.

Carl Laccarino, G. W. Rhein, D. F. Tobias, Louis J. Umile

ENCLOSED TOGGLE SWITCHES to JAN, AN, and MIL requirements. SWITCHES: 14 & 20 position molded (enclosed) or laminated; 3-4-5 position (ganged or single) lever action; and enclosed 6 pole-double-throw per deck; ELAPSED TIME METERS, including sealed and 400 cycle types; FREQUENCY METERS, vibrating reed type, panel or portable including sealed types from 1½", and 2½ reed construction; TEMPERATURE INDICATING INSTRUMENTS. 2" ELECTRICAL INDICATING INSTRUMENTS made by subsidiary, SHURITE METERS. AC & DC Voltmeters, Ammeters, and Milliammeters.

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Brooklyn 4, N. Y.
Booth 2333

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James Vibrapowr Co., Booth 2100
4050 North Rockwell St.
Chicago 18, Ill.

P. T. McCauley, G. W. Price, J. Quigley, John A. Kennedy

Choppers, Vibrators, Power Supplies.

Jennings Radio Mfg. Corp.
970 McLaughlin Avenue
San Jose, California (8)
Booths 3802-3804

▲ J. Emmett Jennings, ▲ Clavin K. Townsend, ▲ Lewis B. Steward, ▲ Hugh C. Ross, Roderick W. Neibour, Robert E. Johnston

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Howard B. Jones Div. Cinch Mfg. Corp.
1026 S. Homan Ave.
Chicago 24, Ill.
Booths 2535-2536

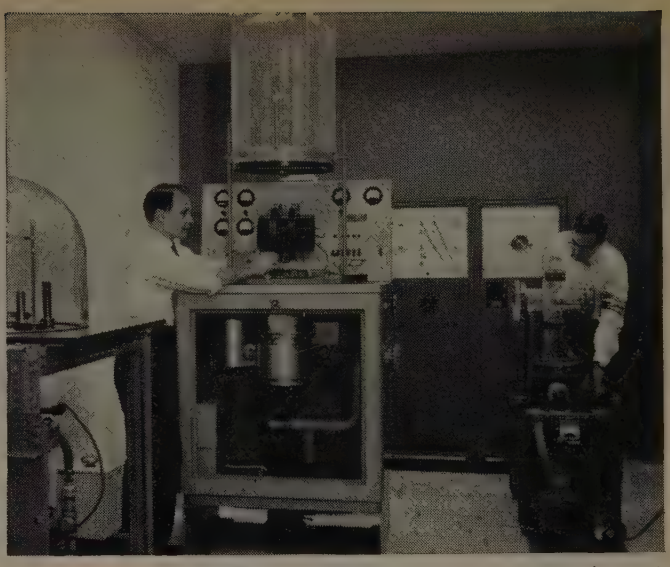
▲ S. Del Camp, H. Z. Benton, ▲ J. R. Hunt, C. W. Nelson

Multi-contact plugs and sockets—barrier terminal strips—fanning strips—terminal panels—fuse mounts.

(Continued on page 320A)



CHEMISTRY. . . Physical, organic, colloid, analytic, biological, and radiation chemistry, in such areas as thin films, polymers, capsular phenomena, photographic systems, membranes, non-mechanical printing techniques, dyes and color studies, elastomers, adhesives, plastics, lubrication, electro-deposition.



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The laboratory, directed by Dr. C. Stark Draper, is famous for outstanding contributions and leadership in the development of high performance control systems making use of an ultimate combination of gyroscopic devices — servomechanisms and electronic components.

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We are leaders in our field and have an outstanding history of accomplishment over the past 15 years. Because of this past record our current assignments are extremely challenging and are extending the boundaries of human knowledge.

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INSTRUMENTATION LABORATORY
Dept. of Aeronautical Engineering, M.I.T.
68 Albany Street, Cambridge 39, Mass.

Whom and What to See at the Radio Engineering Show

(Continued from page 318A)

M. C. Jones Electronics Co., Inc.
185 North Main St., Bristol, Conn.
Booth 3709

▲ M. C. Jones, S. T. Urbank, E. Testa, F. Rookosky, A. Wilkens



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▲ H. R. Foster, ▲ E. E. Crump, ▲ J. Gilmore, ▲ Becker, ▲ K. Scherzer, C. J. Franks, ▲ G. Murphy, ▲ I. Silberg, W. Hamer

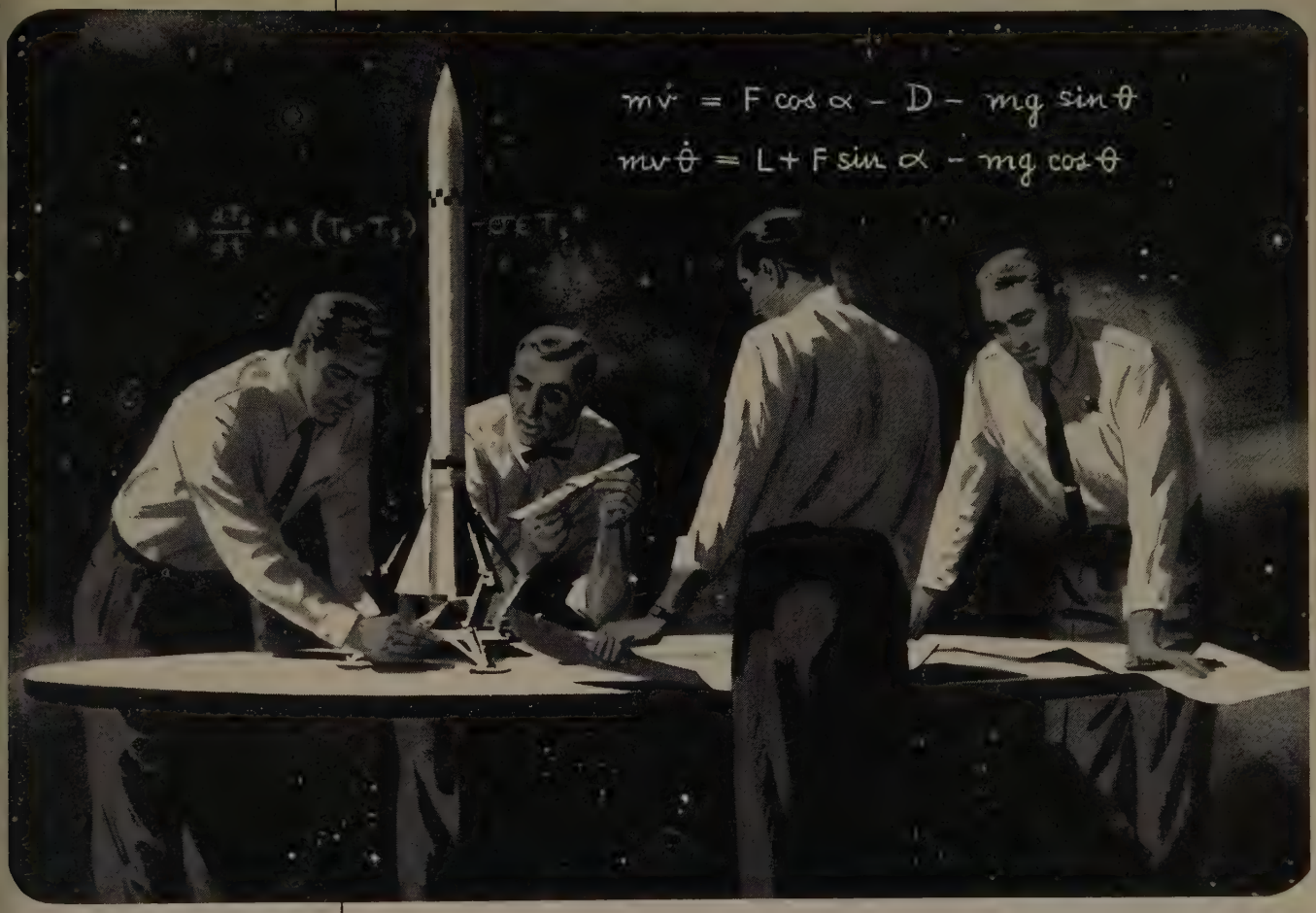


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(Continued on page 322A)

IMPORTANT ACHIEVEMENTS AT JPL



Engineering Teamwork in Missile Development

The Jet Propulsion Laboratory is a stable reseach and development center located north of Pasadena in the foothills of the San Gabriel mountains. Covering an 80 acre area and employing 1700 people, it is close to attractive residential areas.

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Mr. Robert M. Jones

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Palo Alto, California

Whom and What to See at the Radio Engineering Show

(Continued from page 320A)

Kearfott Company, Inc.
Little Falls, N. J.
Booths 1501-1509

W. L. Quigley, I. G. Ennes, V. D. O'Donnell; W. S. Roth; J. Robertson; W. K. Dau, F. J. Beyer, M. F. Perry, C. H. Wheatley, A. Georgia, R. D. Piper, W. S. Smith, W. E. Watson, G. Toker.

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Booth 3115

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* Indicates new product.

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79 West Monroe St.
Chicago 3, Illinois

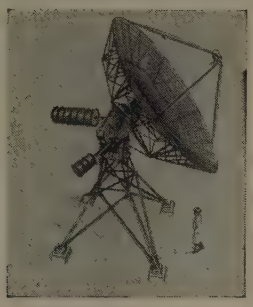
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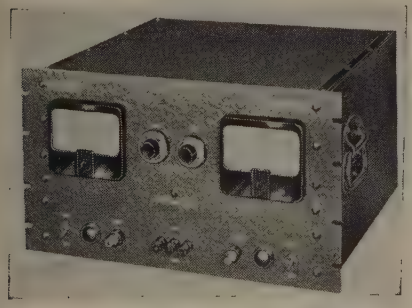
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840 Barry St.
New York 59, N. Y.
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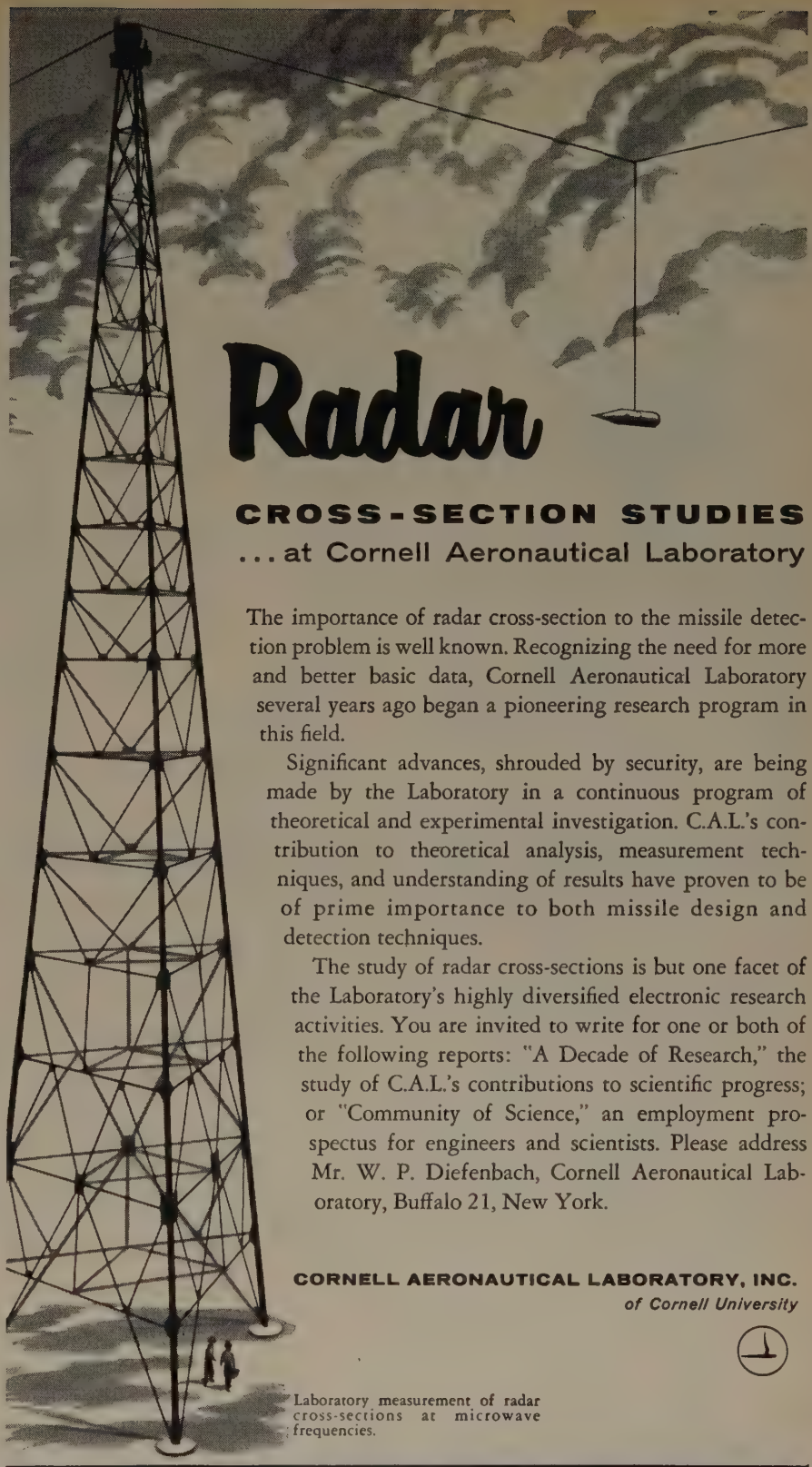
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(Continued on page 324A)



Radar

CROSS-SECTION STUDIES
...at Cornell Aeronautical Laboratory

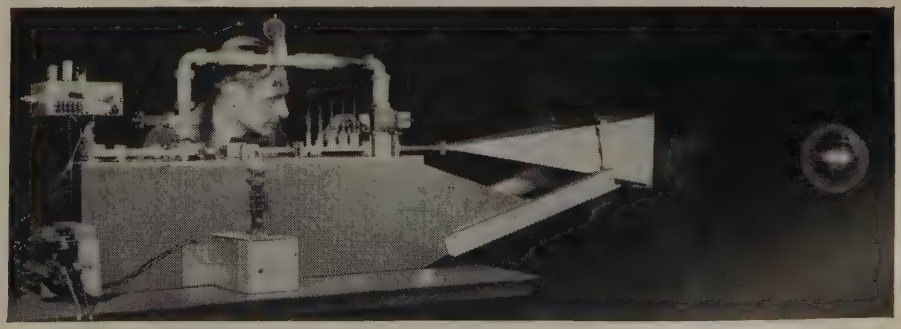
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The study of radar cross-sections is but one facet of the Laboratory's highly diversified electronic research activities. You are invited to write for one or both of the following reports: "A Decade of Research," the study of C.A.L.'s contributions to scientific progress; or "Community of Science," an employment prospectus for engineers and scientists. Please address Mr. W. P. Diefenbach, Cornell Aeronautical Laboratory, Buffalo 21, New York.

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Whom and What to See at the Radio Engineering Show

(Continued from page 323A)

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Keystone Products Co., Booth 2929
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Kings Electronics Co., Inc.
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(Continued on page 326A)



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Applied Research Laboratory, United States Steel Corporation

Monroeville, Pennsylvania

Whom and What to See at the Radio Engineering Show

(Continued from page 324A)

Knight Electronics
109 N. Campbell Ave.
Chicago 12, Ill.
Booth 3928

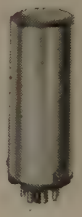
L. S. Preskill, G. Mills, ▲ L. M. Dezettel, ▲ T. Pickering, D. Thorpe



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William Danjczek

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(Continued on page 328A)

* Indicates new product.

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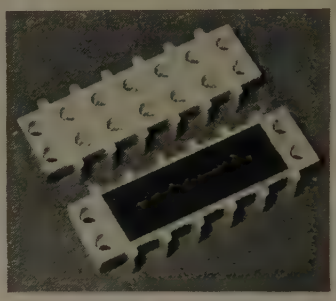
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Whom and What to See at the Radio Engineering Show

(Continued from page 326A)

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633 S. Fulton Ave., Mt. Vernon, N. Y.
Booth 2901

▲ Eugene R. Kulka, William Kulka, Elliott Edelman, Adolph Friedman, ▲ Robert H. Smith, George Antonion, David Friedman



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W. J. Kupfrian, G. L. Cushman, Fred C. Keut

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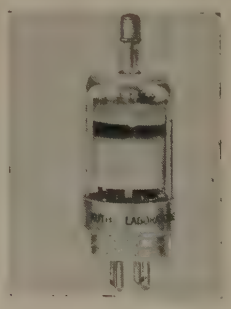
Kuss Industries, Inc., Booth 4049
Tacony & Lewis Sts.
Philadelphia 24, Pa.

F. Kuss, R. S. Kuss, A. H. Eschner, E. Woodward, R. Garrison, W. D. Kneller, Carrol Clemmer

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730 S. 13 St., Newark 3, N.J.
Booths 2510-2625

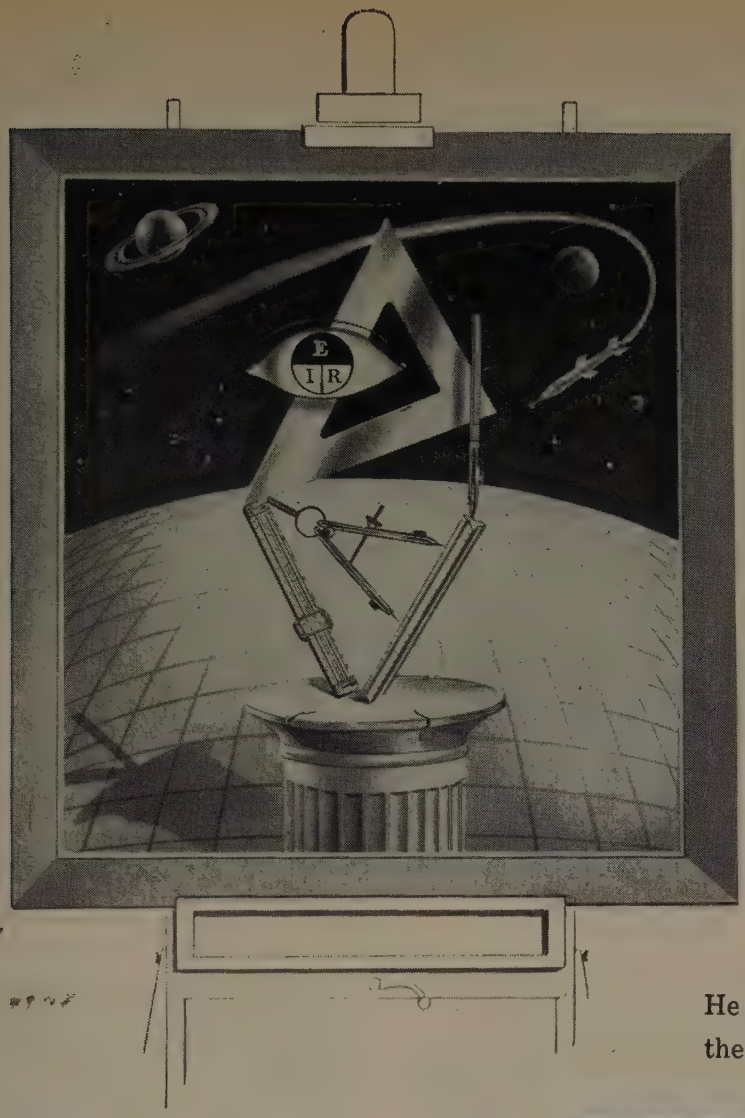
W. P. Maginnis, R. H. Bloemeke, J. J. Meyers, A. E. Gordon, H. M. Brady, S. J. Cohn, L. Feldt



Hydrogen filled diodes. Hydrogen thyratron tubes.

(Continued on page 330A)

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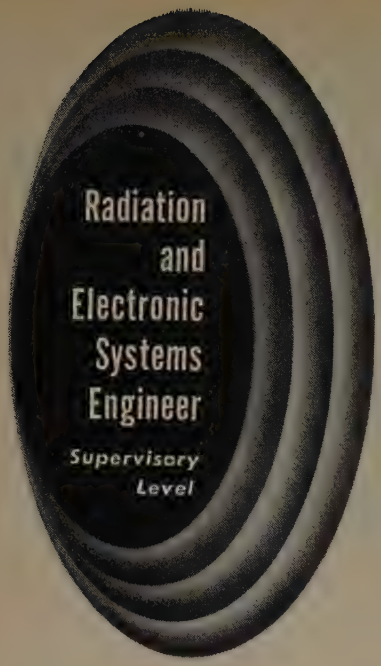


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Institute of Radio Engineers
1 East 79th St., New York 21, N.Y.

Whom and What to See at the Radio Engineering Show

(Continued from page 328A)

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Low Noise wideband Telemetering Preamplifier. Transistorized 40 Mc Dual Conversion receiver IF Strip. Narrow Bandpass 150 MC single conversion Receiver using crystal filter and discriminator. Radar and Missile IF Amplifiers.

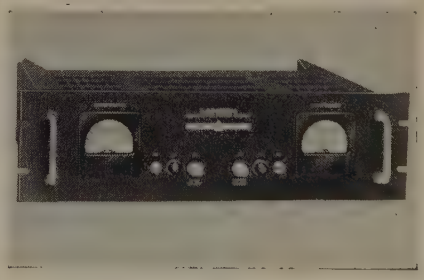
Laboratory for Electronics, Inc.
75 Pitts St., Boston 14, Mass.
Booths 3207-3209

J. C. Worth, S. M. Golembe, F. A. Hickok, D. M. Powers, P. Pollins, H. W. Harding, W. B. Palioca, R. K. Mosher, J. McCann, T. Erwin, I. Versoy, E. Herbert, W. Charow, R. Micol, F. Neri, R. Rogers

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Booths 2436, 2438

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(Continued on page 331A)

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(Continued from page 330A)

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▲ Jan H. Stillbach, Joseph G. Stalk, Jr., William Gorman, Harry Arrelman

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L. Larson, D. Tower, C. Briggs, R. Smith, G. Adams, L. Gercken, F. Whiteside, R. Springfield

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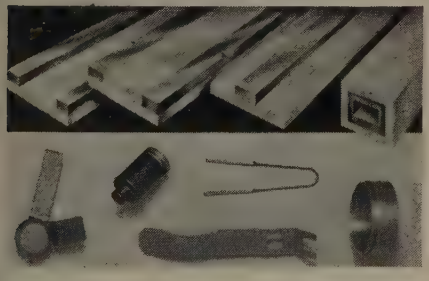
Lavoie Laboratories, Inc.
Matawan—Freehold Road
Morganville, N. J.
Booths 3242-3244

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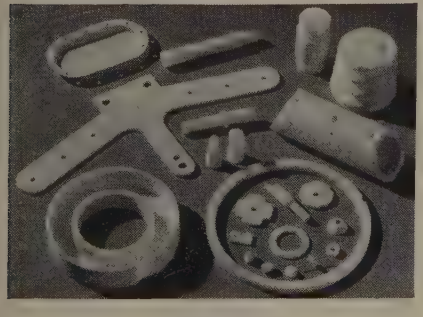
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(Continued on page 332A)

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to
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in
these fields

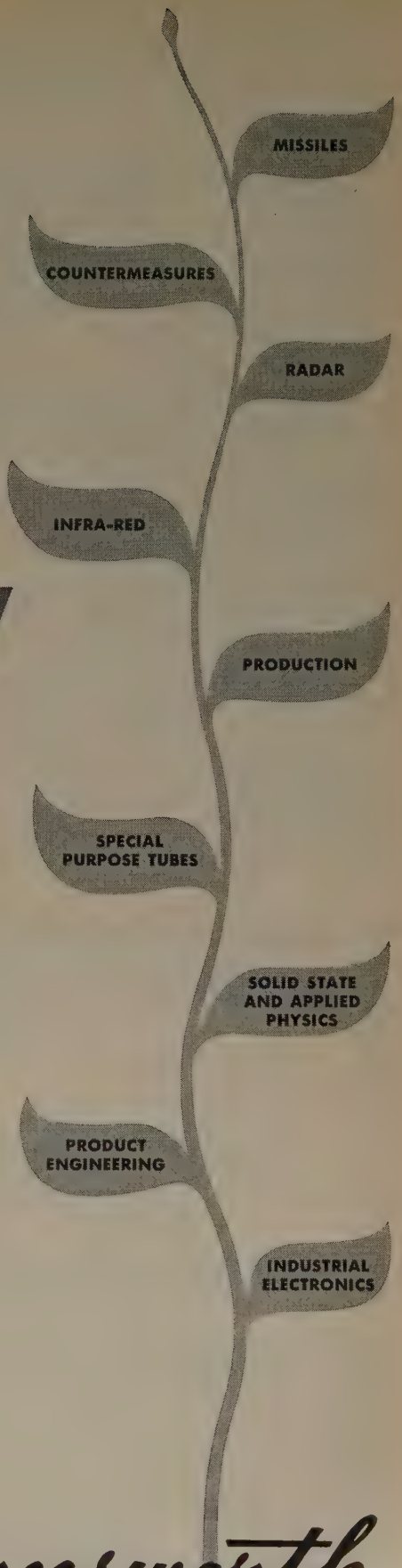
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Whom and What to See at the Radio Engineering Show

(Continued from page 331A)

G. H. Leland, Inc., Booth 2214
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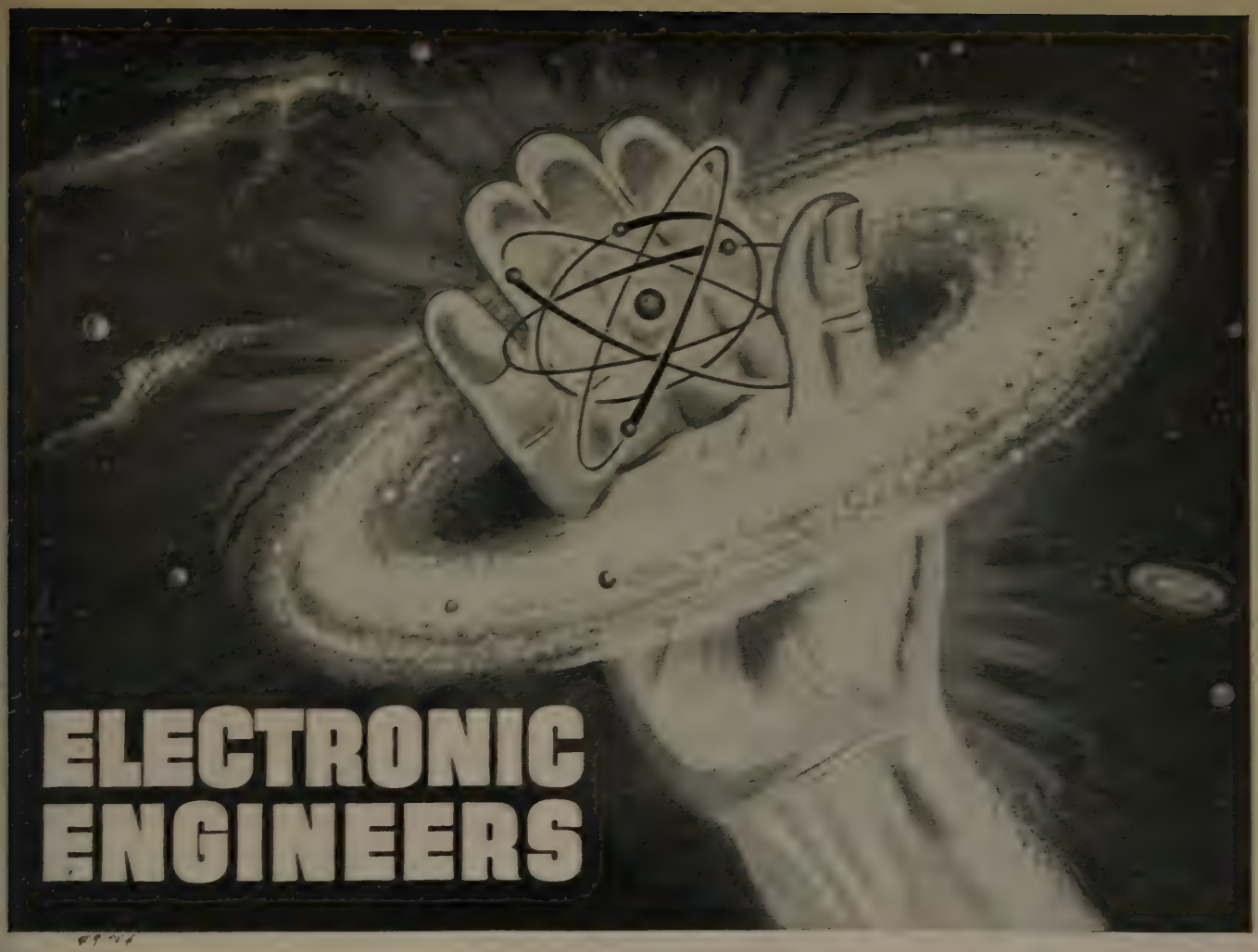
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(Continued on page 334A)

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Whom and What to See at the Radio Engineering Show

(Continued from page 332A)

LIECO, Inc.
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Oceanside, L. I., N. Y.
Booth 3235

Abe Zeitz, ▲ Martin Zanichkowsky, Larry Willis, Nat Paul, ▲ Sam Glassman

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Linde Air Products Co., Division Union Carbide and Carbon Co., Booths 2822–2828
Elizabeth, N. J.

C. Barry, T. A. Marsal, D. R. Ogden, J. J. Burke

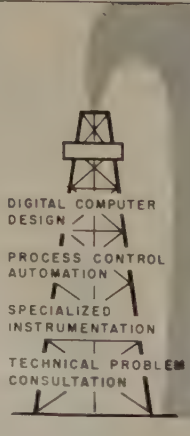
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Lindgren, Eric. A., Booth 1924
4515-17 N. Ravenswood Ave.
Chicago 40, Ill.

E. A. Lindgren, Ben Farmer, Clarice Walsh, C. Pitchford, W. B. Cozzens, M. Cudahay, J. Feelex, W. B. Taylor, C. Paddock

Testing Chambers for Electronic Equipment

(Continued on page 336A)



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Whom and What to See at the Radio Engineering Show

(Continued from page 334A)

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(Continued on page 338A)

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(Continued from page 337A)

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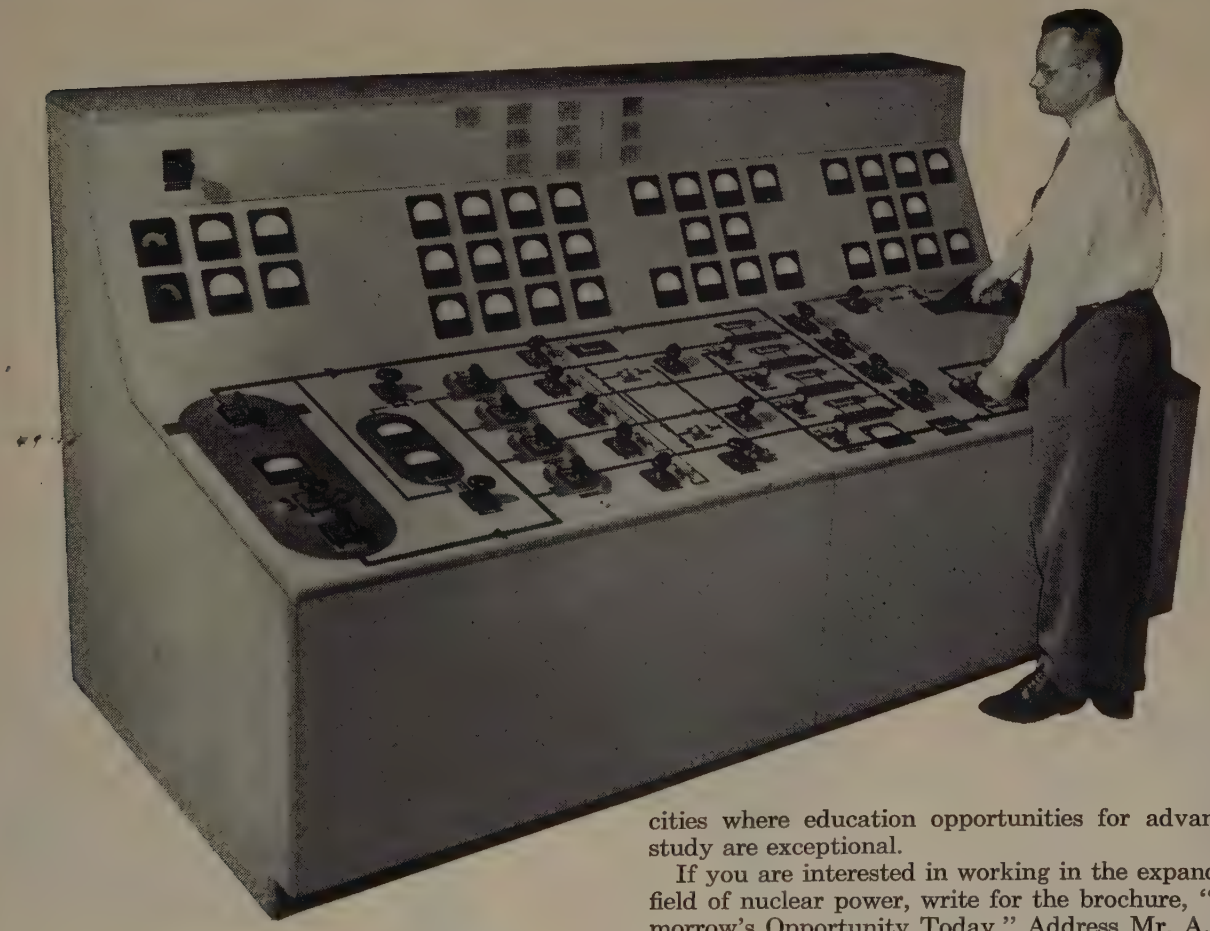
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(Continued from page 338A)

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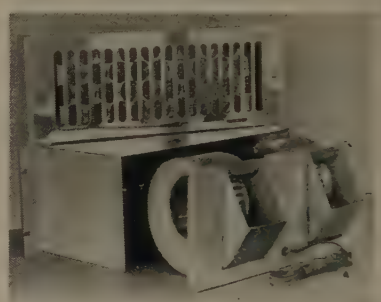
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(Continued on page 344A)

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Whom and What to See at the Radio Engineering Show

(Continued from page 342A)

Mepco, Inc.
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Morristown, N. J.
Booths 2802-2804

Len Kirby, Jr., Edward L. Beaudry, Jr., K. W. Feather, J. K. Savage, Jr., George Engert, G. A. Erickson, J. A. Armstrong

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*Copper cored sealing wire; tin clad nickel for transistor mfg.; clad metals for electronic uses, such as copper clad aluminum, copper clad hard-enable steel, aluminum clad iron, nickel clad iron; aluminum-nickel clad iron for vacuum tube plate stock; thermostat metals; and electrical contacts; precision switches.

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John Kreuter, Robert Montgomery, E. J. Lever

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▲ Benjamin R. Kamens, Ivan I. Bezugloff, Jr., James S. McElroy

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Micamold Electronics Corp., Booth 2217
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Brooklyn 37, N. Y.

A. S. Gartner

Capacitors, filters, delay lines.

Microdot, Inc., Booths 2101-2103
1826 Fremont Ave.
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Gordon P. Felts, ▲ W. F. Cox, H. A. Lichtenecker, ▲ Guy Martin

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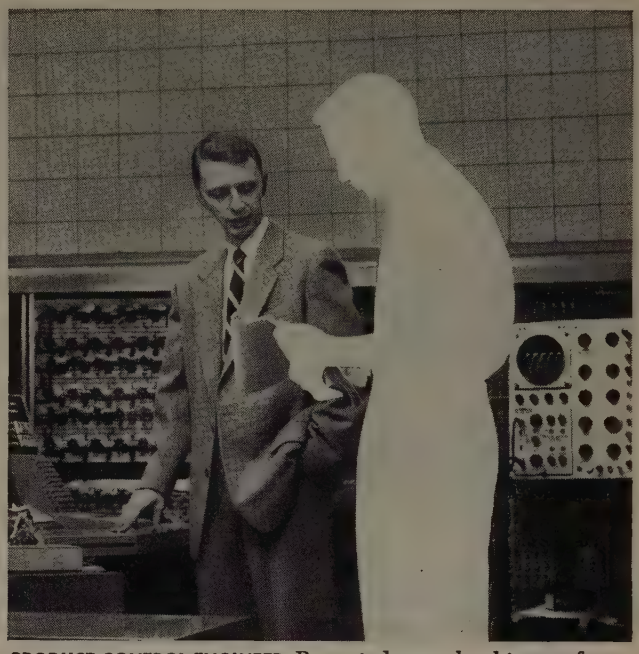
(Continued on page 346A)

* Indicates new product
▲ Indicates IRE member

IBM GROWTH promoted these men



PRODUCT DEVELOPMENT ENGINEER: Before his recent promotion, this man was a member of a small engineering "team" (two M.E.'s, an E.E. and a model maker) in IBM's Poughkeepsie plant. His specific project entailed the creation of the "ultimate package in printed circuitry." His group "brainstormed" the project in continual sessions, putting the results in model form. Then the group would try to "tear the idea to shreds" in order to create something even better.



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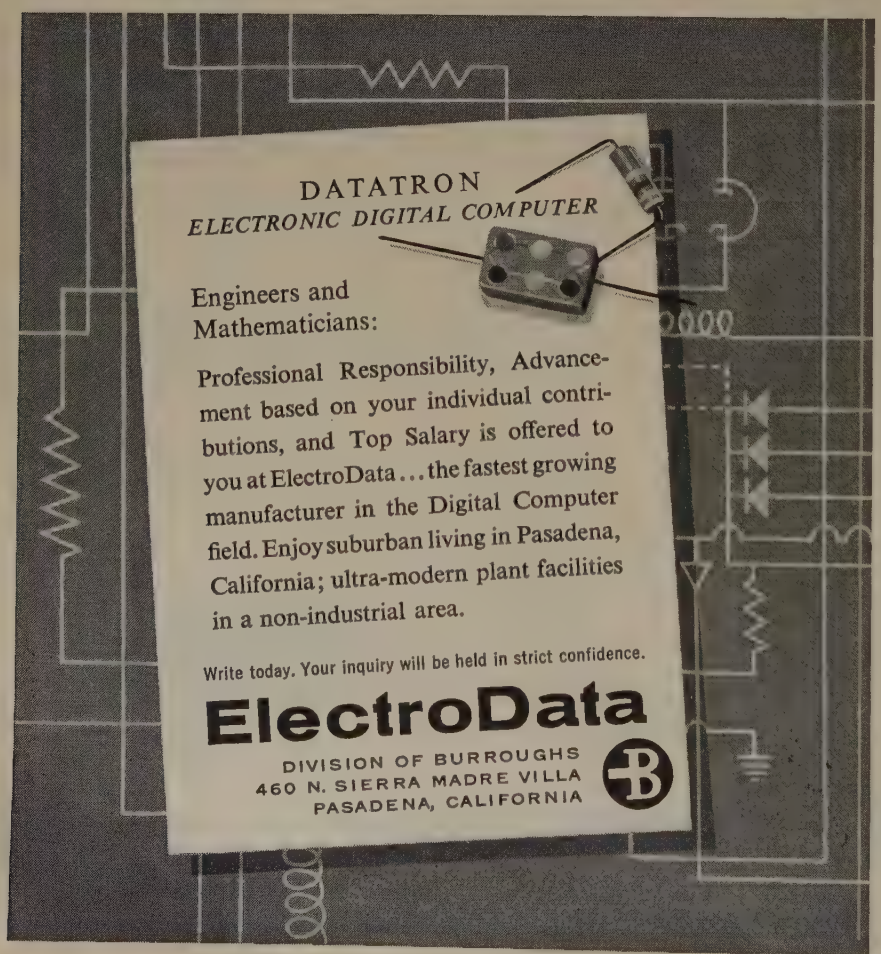
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Whom and What to See at the Radio Engineering Show

(Continued from page 344A)

Micromech Mfg. Corp., Div. of Sanford Mfg. Corp., Booth 4035
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Union, N. J.

C. E. Falcone, John Santillo, Al Grand, Anthony Grillo, R. E. Tucker

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Micro Switch Div., Booths 2202-2212
See Minneapolis-Honeywell Reg. Co.

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(Continued on page 348A)

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ELECTRONIC SYSTEMS SPECIALISTS

A message of interest to all electronics men

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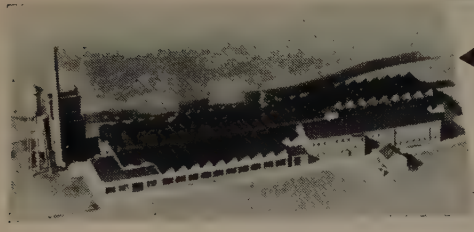
*Other firsts were Republic's Thundercraft, latest, most lethal and versatile of which is the incredible F-105 Thunderchief, supersonic USAF fighter-bomber, capable of delivering nuclear loads.



▲ Plant of Westchester manufacturing subsidiary, Pleasantville Instrument Corporation; additions are under construction.

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Whom and What to See at the Radio Engineering Show

(Continued from page 346A)

Midwestern Instruments, Booth 3103
41st & Sheridan Road
P. O. Box 7186
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▲ G. R. Morrow, A. E. McCoy, F. B. Cope, Dan Holloway, Ken Denny, Frank E. Westerman

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▲ Dr. W. K. Volkers, ▲ W. Hartley, ▲ D. Morey, ▲ D. Bojarski, ▲ R. Tanis, ▲ D. J. Volkers

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Milwaukee Gas Specialty Co., Booth 2709
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Subminiature Switches: Single pole double throw center positions off toggle switch. Three pole on-off toggle switch. Three pole on-off pushbutton switch.

(Continued on page 350A)

* Indicates new product
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Whom and What to See at the Radio Engineering Show

(Continued from page 348A)

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T. C. Witter, R. W. Weber

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Electronics Division
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▲ Monroe H. Postman, William L. Slover, John Scully

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▲ Paul L. Irvine, A. E. W. Hibbitt, J. K. Pudney, R. J. White, A. Roy Smith

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(Continued on page 352A)

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MOTOROLA

Whom and What to See at the Radio Engineering Show

(Continued from page 350A)

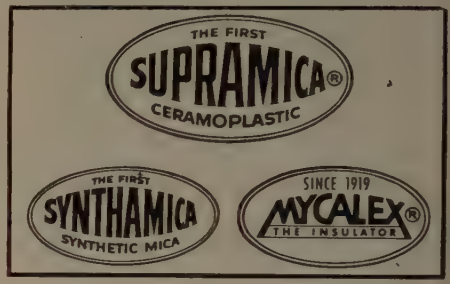
Mutual Electronic Industries Corp., Universal Aviation Div., Booth 3313
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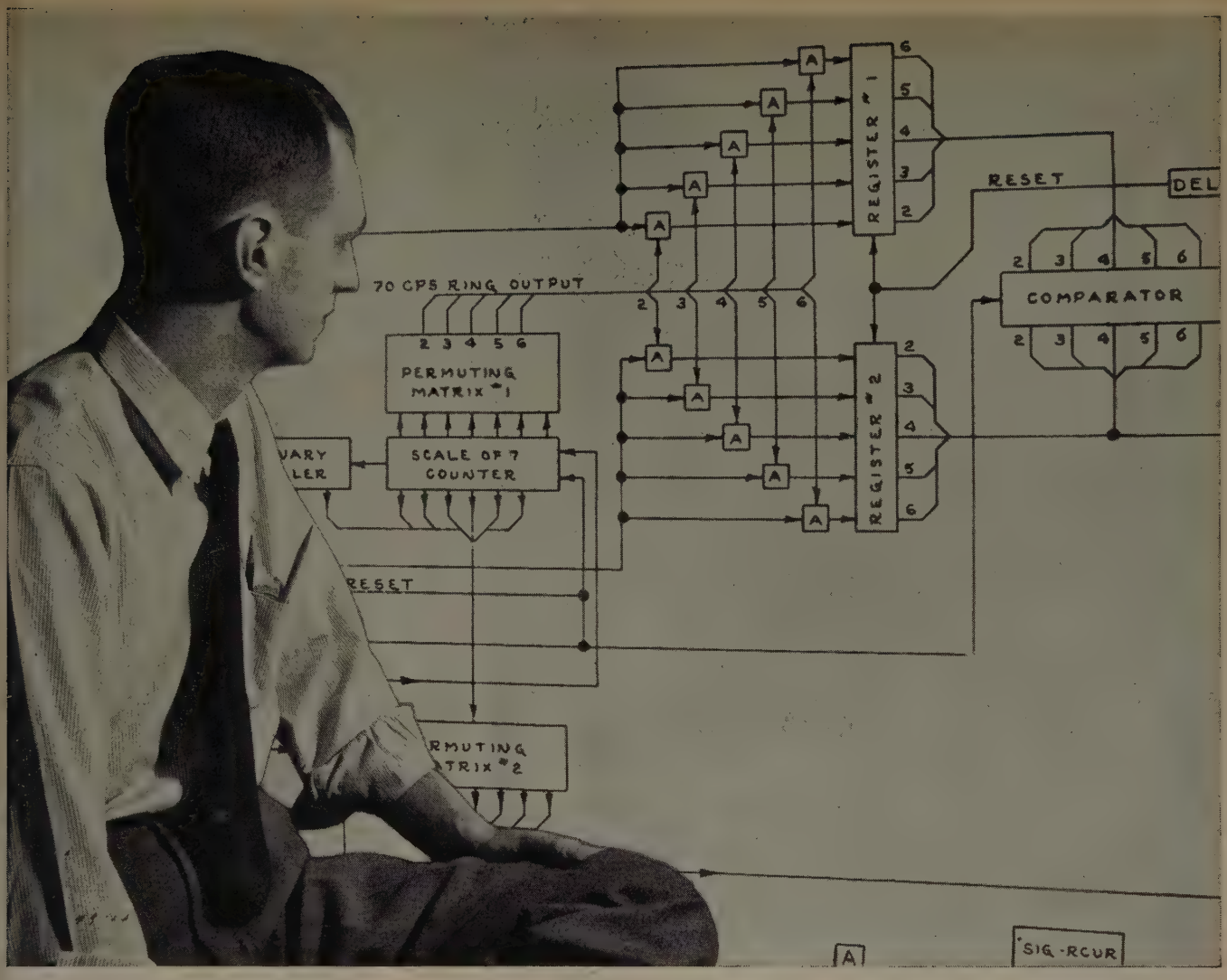


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(Continued on page 354A)

Children under 18 are not permitted on the Radio Engineering Show floor. Please do not plan to bring your youngsters with you to the Show. A hospitality room will be provided by the show management where children may wait for parents attending the show.



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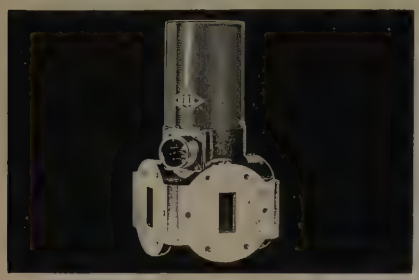
STROMBERG-CARLSON COMPANY
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Whom and What to See at the Radio Engineering Show

(Continued from page 352A)

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(Continued on page 356A)

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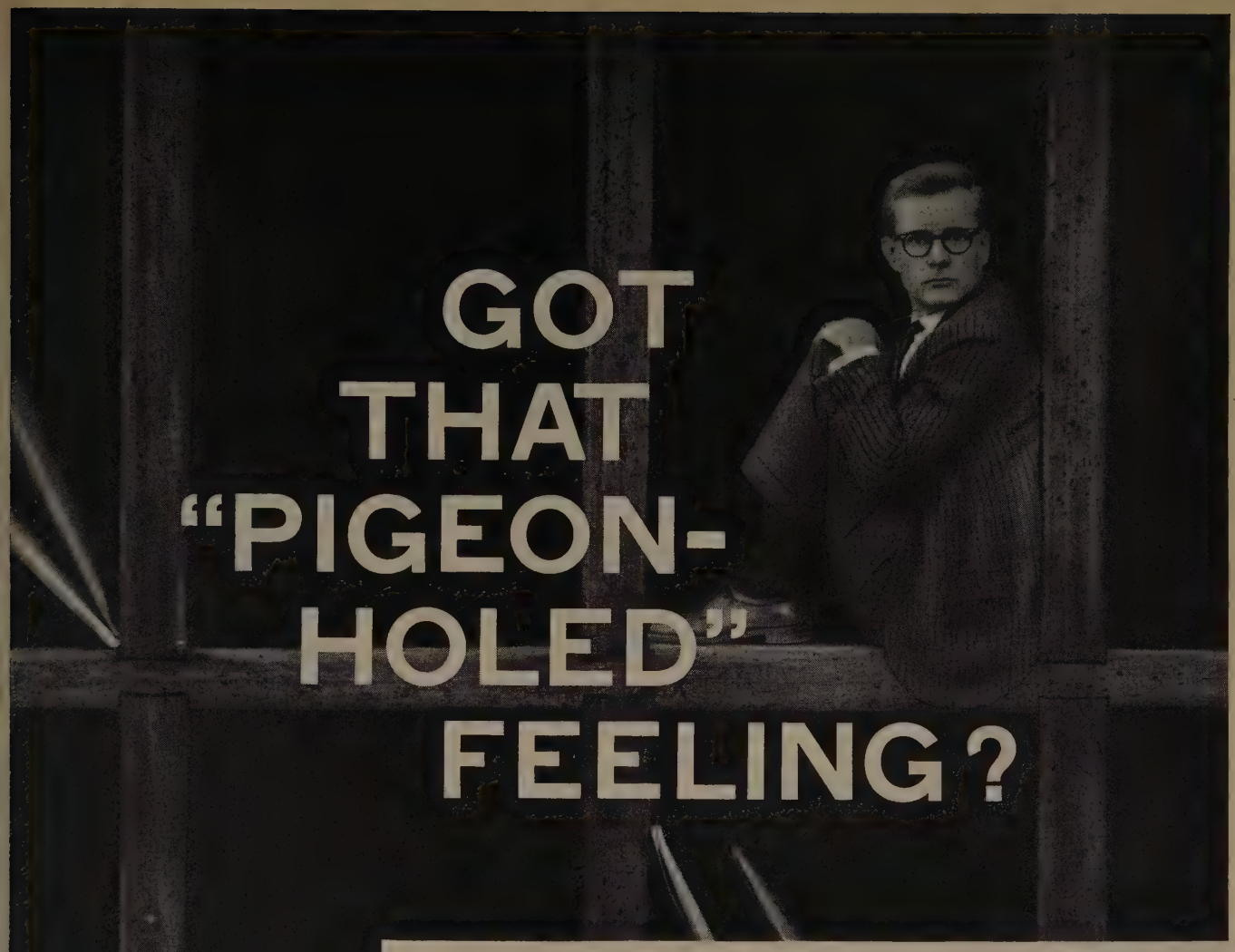
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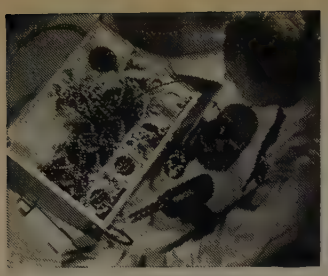
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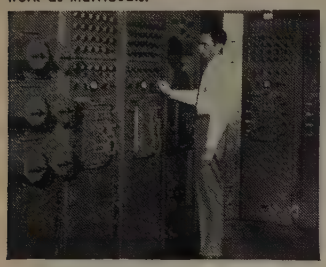
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(Continued from page 354A)

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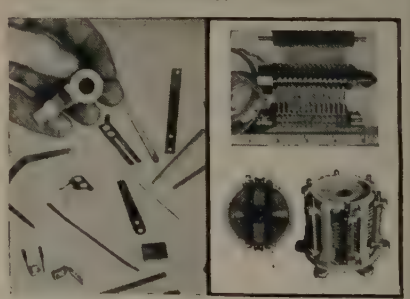
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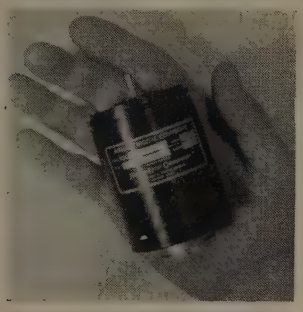
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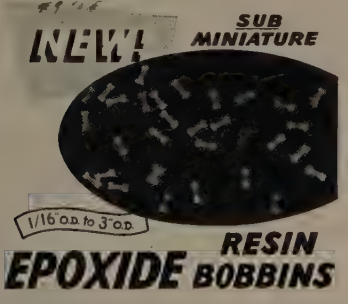


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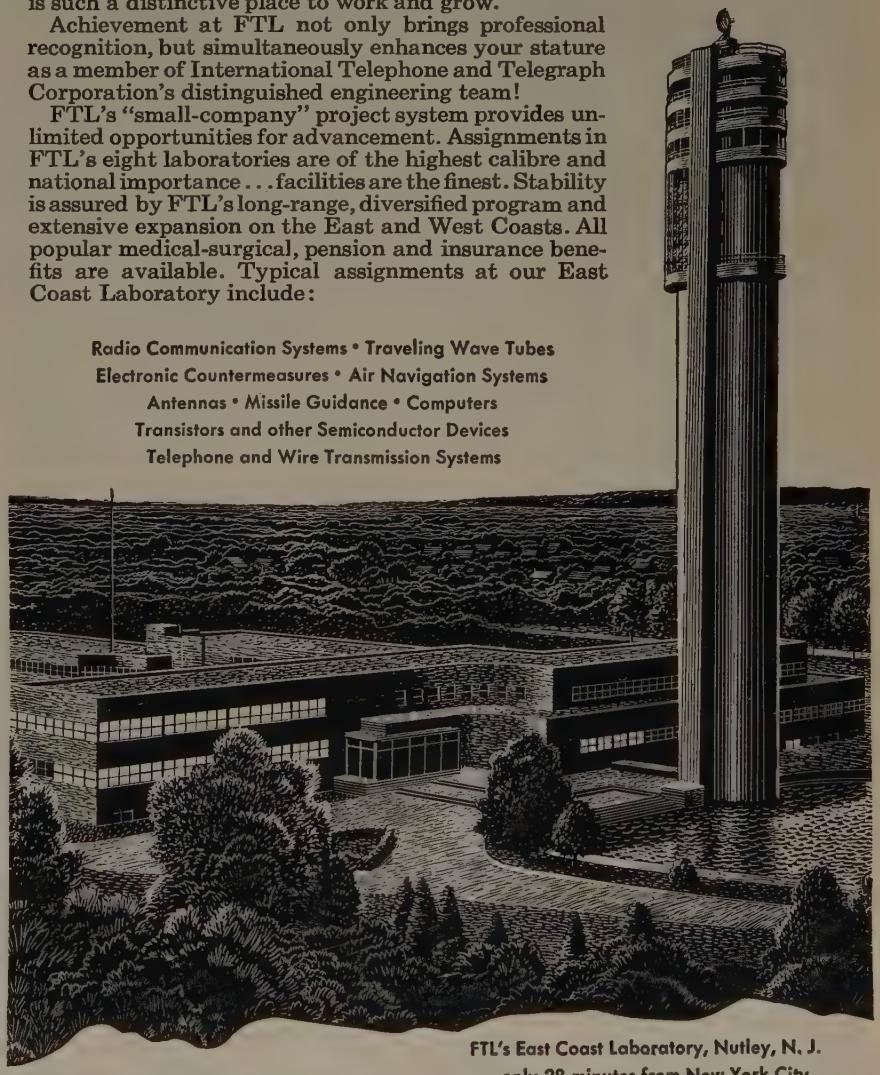
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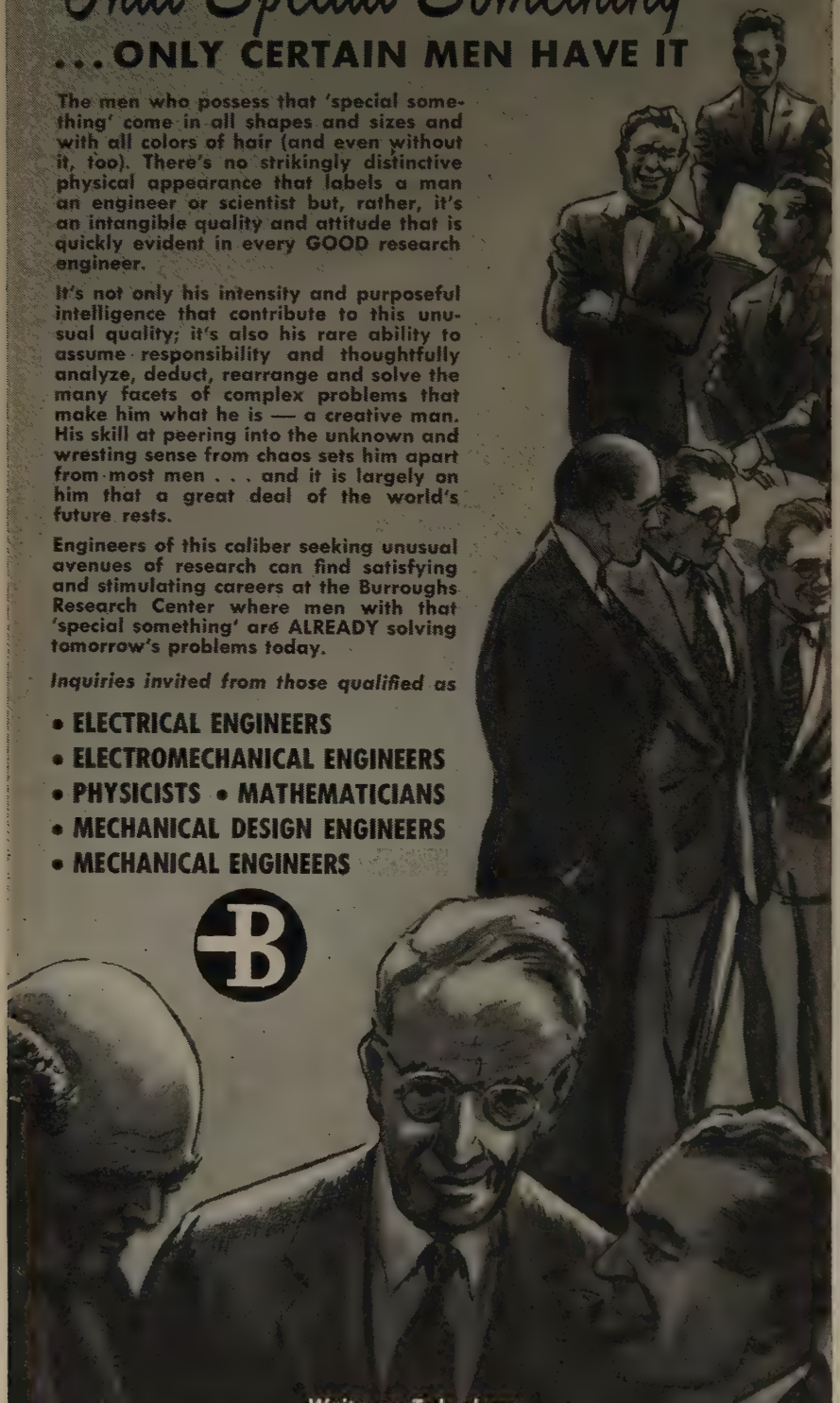
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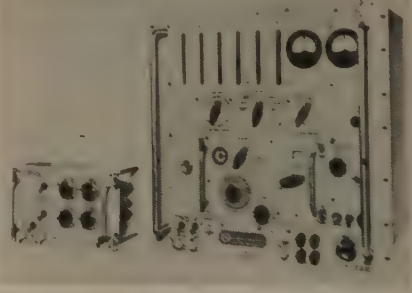
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(Continued on page 360A)

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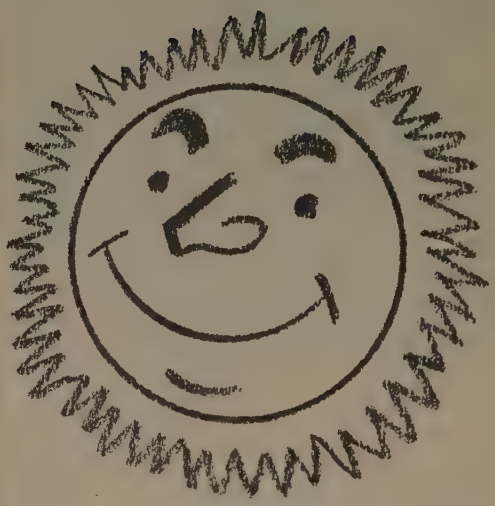
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(Continued from page 358A)

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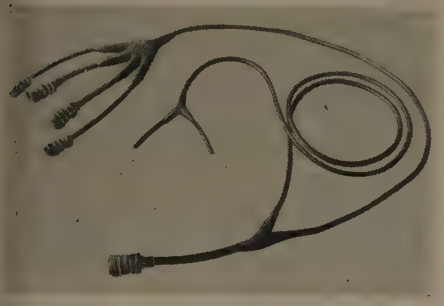
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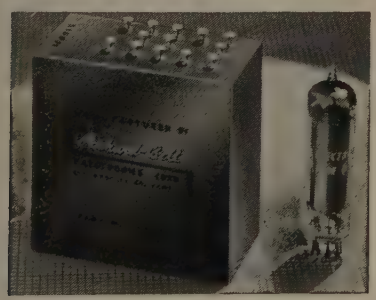
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(Continued on page 362A)



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Whom and What to See at the Radio Engineering Show

(Continued from page 361A)

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(Continued on page 364A)

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- 3.2 Telemetry
- 3.3 Data Reduction
- 3.4 Data Analysis
- 3.5 Project Engineering
- 3.6 Data Process Planning
- 3.7 Control Circuitry Design

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- 4.2 Airframe Performance
- 4.3 Weapons Control
- 4.4 Operations Research
- 4.5 Radar
- 4.6 Error Analysis
- 4.7 Reliability

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- 5.1 Transistors
- 5.2 Magnetic Amplifiers
- 5.3 Synchros
- 5.4 Tachometers
- 5.5 Accelerometers
- 5.6 Resolvers
- 5.7 Integrators

6.0 RADAR
- 6.1 CW Doppler Systems
- 6.2 Antenna Design
- 6.3 Components
- 6.4 Pulse Circuitry
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- 6.6 Laboratory Evaluation

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(Continued from page 362A)

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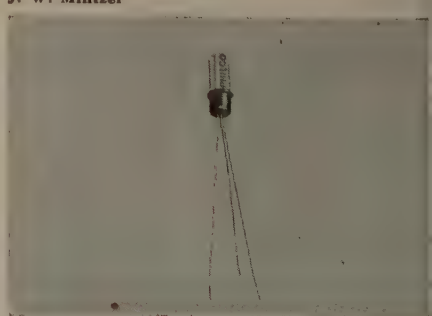
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(Continued on page 366A)

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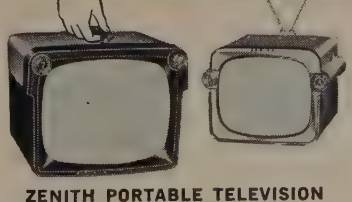
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Whom and What to See at the Radio Engineering Show

(Continued from page 364A)

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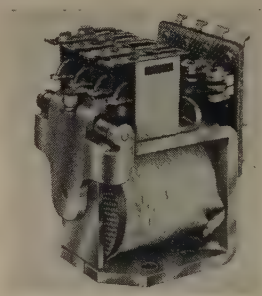
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(Continued on page 368A)

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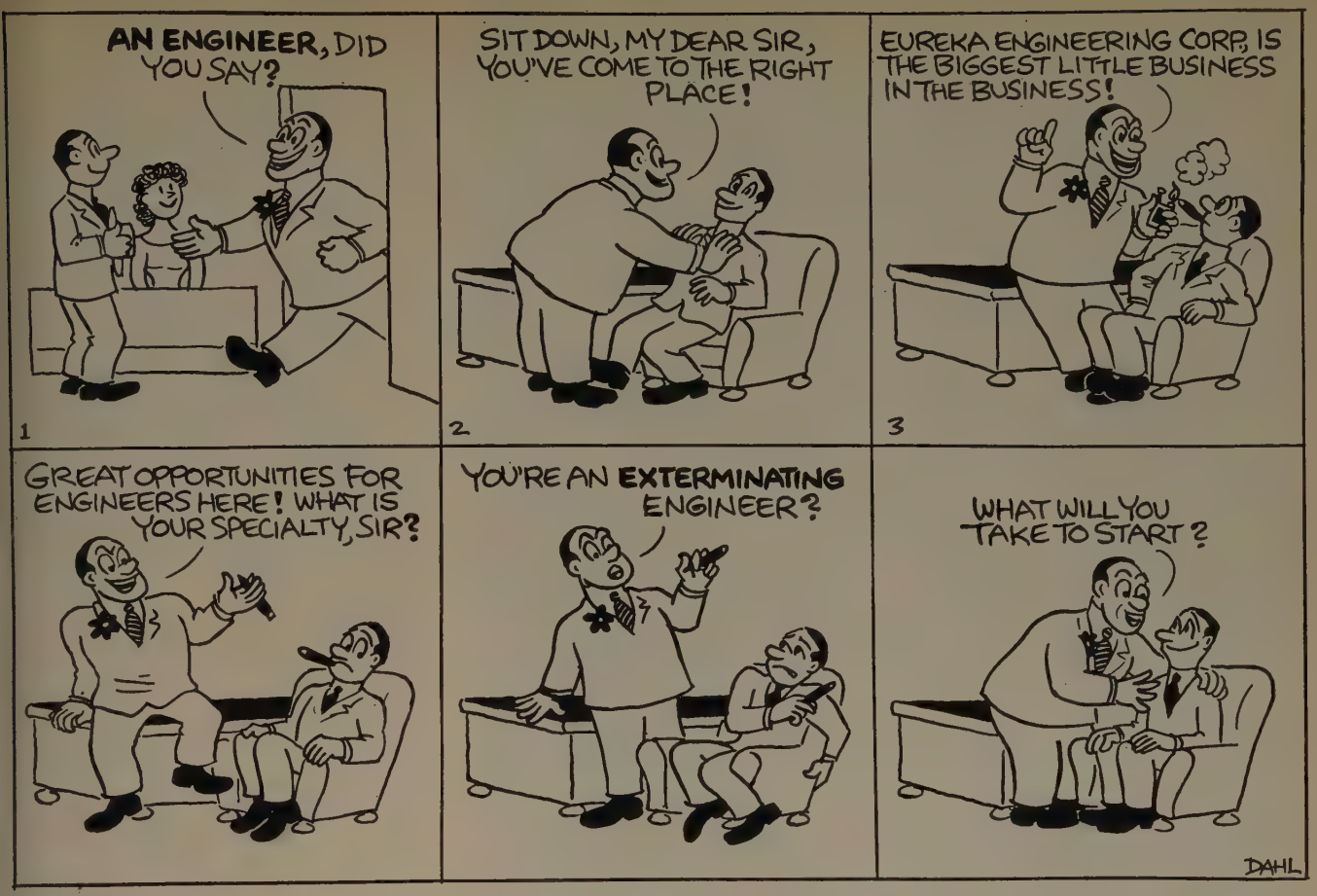
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Whom and What to See at the Radio Engineering Show

(Continued from page 366A)

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(Continued on page 369A)

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Whom and What to See at the Radio Engineering Show

(Continued from page 368A)

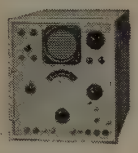
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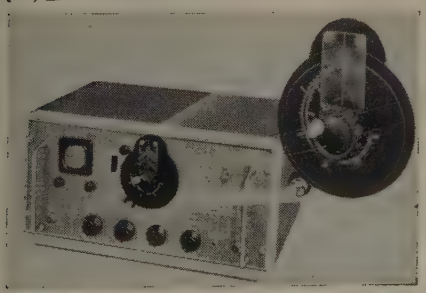
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(Continued on page 370A)





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Whom and What to See at the Radio Engineering Show

(Continued from page 369A)

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(Continued on page 372A)

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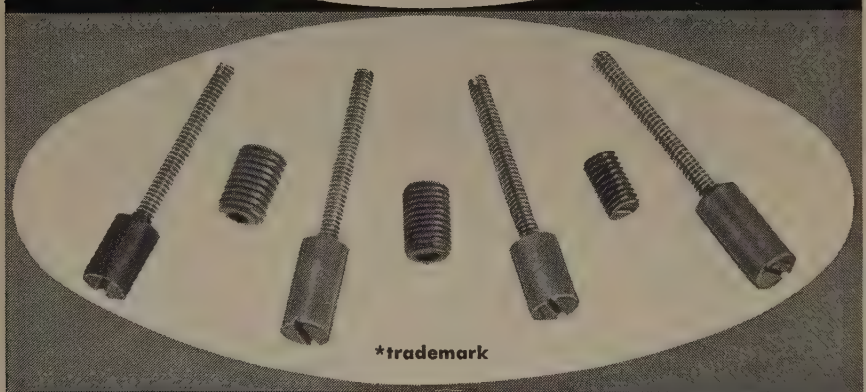


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(Continued from page 370A)

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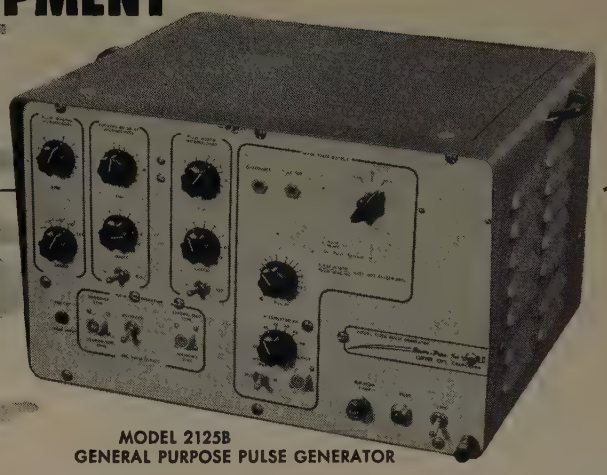
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(Continued on page 374A)

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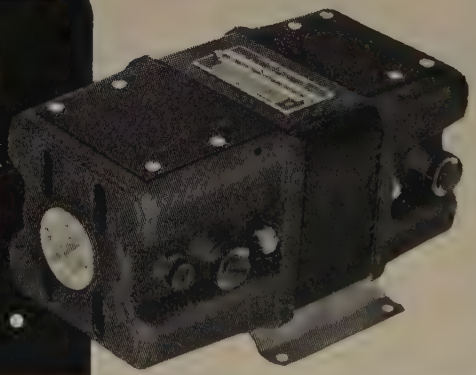
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(Continued on page 376A)

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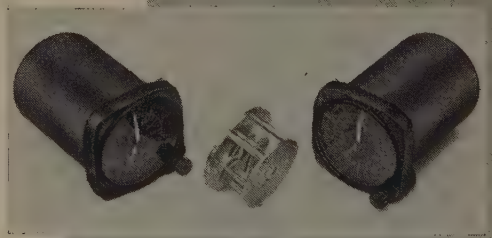
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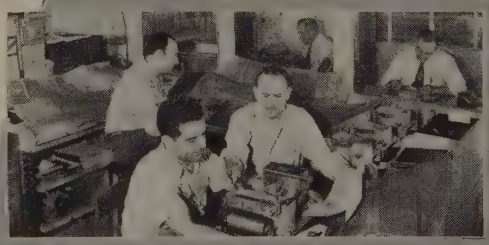
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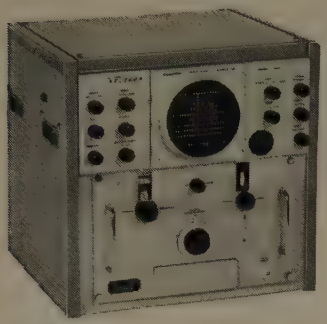
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(Continued from page 374A)

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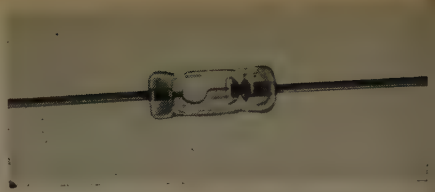
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Booth 1309

Robert Ashley, John Clarke, Elliot Diamond, Laurence LeBow

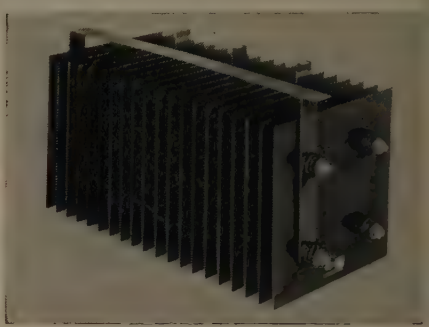


Gold bonded germanium diode

Engineers working with transistorized circuits, computers, etc.; RRco DR385 has controlled forward voltage drop between 0.34 and 0.37V @ the 10ma level. Check our specs!

Radio Receptor Co., Inc.
Selenium Department
240 Wythe Ave., Brooklyn 11, N. Y.
Booth 1307

Julian Loebenstein, Stanley Kramer, Seymour Durocher, Alvin Genser, Frank Caizzo



HCD Petti-Sel Selenium Rectifier

HCD "PETTI-SEL" SELENIUM RECTIFIERS featuring estimated life of 100,000 hrs. small size, and low forward voltage drop.

The Ramo-Wooldridge Corp.
5730 Arbor Vitae St.
Los Angeles 45, Calif.

Booth 1901

Elliott L. Lewis, Eugene M. Knight, Richard R. Elwell

Engineering Systems Technology

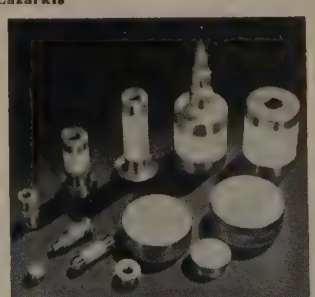
Rawson Electrical Instr. Co., Booth 3309
110 Potter St.
Cambridge 42, Mass.

Morley J. Lush

Wide-Range Wattmeter for DC to 1000 cps. A line of Rotating Coil Gaussmeters. Panel Mounting Meters. Electrostatic Voltmeters. Thermocouple Meters. Fluxmeters. High Sensitivity and High Accuracy Laboratory Meters.

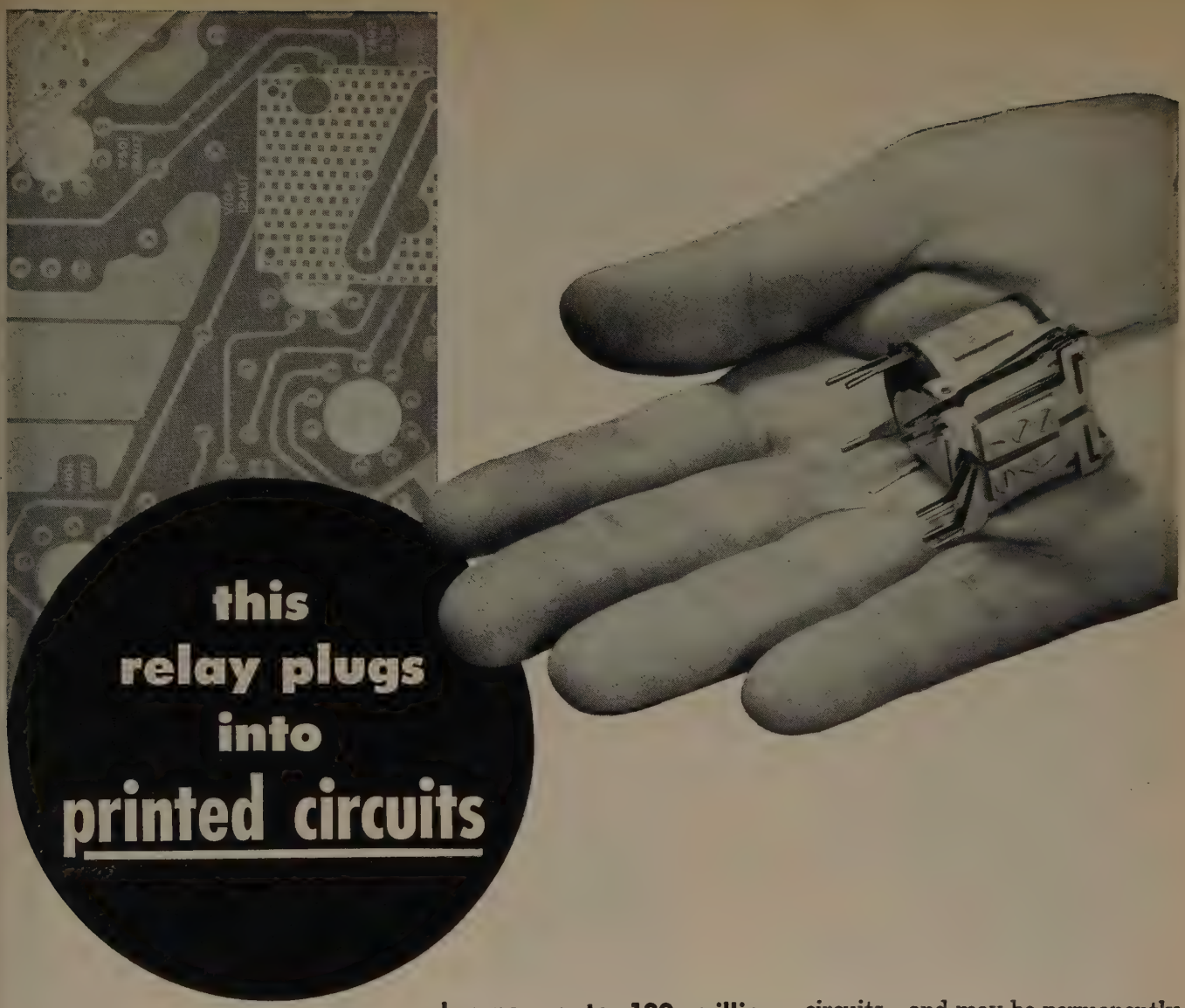
Raytheon Manufacturing Co.
Ceramic Sales Dept.
Foundry Avenue, Waltham 54, Mass.
Booths 2611-2614

P. J. Lazarkis



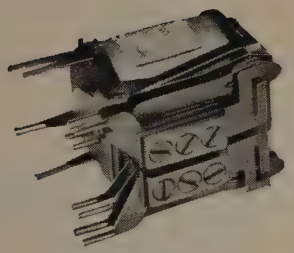
High-Alumina Ceramics: Tubing, Tube Spacers, Rods, Discs, Bushings, Washers, Windows, Rings, and Metallized Ceramics. .Ceramic-Metal Assemblies, Vacuum Seals, Ceramic Terminals and Connectors.

(Continued on page 378A)



this relay plugs into printed circuits

. . . and runs up to 120 million operations without attention.



HELPFUL INFORMATION FOR THE TECHNICALLY MINDED . . .

Dimensions: Length, 1 ¾"; height, 1 5/16" to 1 ¾" (depending upon the number of contact springs); width, 1".

Operating Voltage: Up to 175 volts, dc, only.

Contact Spring Capacity: Maximum of 9 springs per pile-up.

Springs: Can be made of phosphor-bronze, "Bronco" metal, or other special purpose materials, as required.

A new stainless-steel armature bearing pin, a new sintered metal yoke, a new lubricating system for the armature—these features add up to 10 times the life of former relays. Automatic Electric Printed-Circuit Relays meet today's needs in automation, in computers, in any applications requiring utmost dependability.

Specially designed plug-in terminals are an integral part of the coil and of the contact springs. They make firm, tight, high conductivity connections with printed circuits—and may be permanently secured by using any recognized soldering technique.

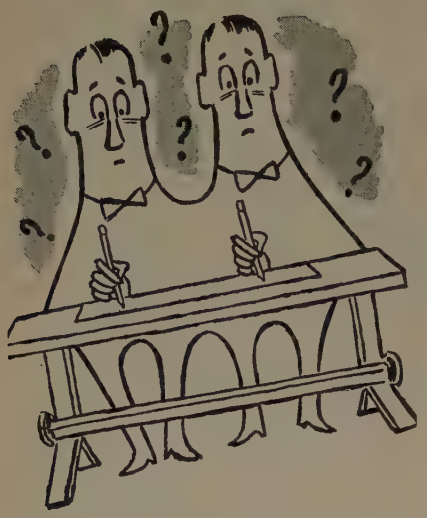
Besides these features, you get efficient magnetic design, permanently welded contacts, "stay-put" contact springs and many other advantages found in all Automatic Electric relays. Save parts, assembly and wiring time by using printed circuits—and Automatic Electric Printed-Circuit Relays. For complete details, *write:* Automatic Electric Sales Corporation, 1033 West Van Buren Street (HAymarket 1-4300), Chicago 7, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. *Offices in principal cities.*

AUTOMATIC ELECTRIC

Originators of the dial telephone • Pioneers in automatic control

GENERAL TELEPHONE SYSTEM

beside yourself?



Broad Band amplification problems got you seeing double? Call the guy from I.F.I. His singular ability to dovetail detail with vision and know-how makes him a welcome sight.

I.F.I.'s Model 395 "Super Video" Wide Band Amplifier is designed to provide a bandpass beyond that of a normal video amplifier.

A self contained unit mounted in a cabinet topped with carrying handle, it may be used to increase the sensitivity of a frequency counter. A counter requiring 1 volt to actuate can be used to count a signal as small as 300 microvolts! In the lab it is a most useful factor because its high gain enables it to be driven from a crystal detector, resulting in a wide band crystal video receiver. The power output of signal generators are greatly augmented by its use.

So see the man from I.F.I. who will show you the great advantages in the use of the unit he is proud to represent, I.F.I.'s newest Model 395 "Super Video" Wide Band Amplifier.

SPECIFICATIONS

Bandpass	1 Kc to 50 Mc
Gain	70 db
Input Impedance	90 ohms
Output Impedance	90 ohms
Output Voltage Capability	More than 1V. rms
Noise Figure	15 db
Tube Complement	24-6AK5's 1-5R4-GY
Gain Control provided on front panel	
Rise Time	10 millimicro-seconds

P.S. Are you a qualified engineer interested in doubling your possibilities in your chosen field? Don't think twice... Call on us, pull up a chair and we'll talk, in complete confidence, about joining our growing forces at I.F.I.

INSTRUMENTS ifi INC. FOR INDUSTRY

INSTRUMENTS FOR INDUSTRY, INC.
151 Glen Cove Rd., Mineola, N.Y. • Pioneer 2-5300

See you at IRE Show—Booth #2830

Whom and What to See at the Radio Engineering Show

(Continued from page 376A)

Raytheon Manufacturing Co.
Equipment Marketing Division
103 River Street, Waltham 54, Mass.
Booths 2611-2614

William Buck, Wm. Weed, Gene Clark, Howard Burgess, Donald Whittemore, George Zipf



Power Supply Assembly

Evaporative cooling—new transformer design technique provides drastic size and weight reduction in high voltage transformer design. New complete line of Test Jacks and Binding Posts.

Raytheon Manufacturing Co.
Microwave & Power Tube Operations
Foundry Avenue, Waltham 54, Mass.
Booths 2611-2614

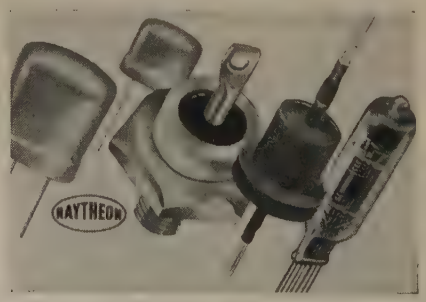
A. F. Giacolone, J. S. Graham, T. S. Hurley, R. A. Lee, R. A. Peterson, G. G. Robichaud, R. H. Stone



AMPLITRON: Heat of M.T.I. radars of the future—Backward Wave Oscillators—Recording Storage Tubes—Magnetrons—Klystrons.

Raytheon Manufacturing Co.
Receiving and Cathode Ray Tube Operations
55 Chapel Street
Newton 58, Massachusetts
Booths 2611-2614

▲ V. Altomare, ▲ R. Knowles, G. Greenstein, F. Schillinberge, ▲ C. W. Martel



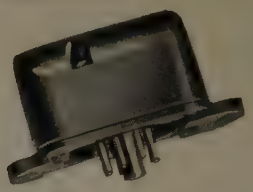
Silicon Rectifiers, Transistors and Diodes. Germanium Transistors and Diodes. Reliable Miniature and Subminiature Tubes. Special Cathode Ray Tubes. Receiving, Television and many types of special Tubes.

(Continued on page 380A)

* Indicates new product
▲ Indicates IRE member

THE MARK OF QUALITY
BARBER COLMAN

quick solutions to various electronic problems



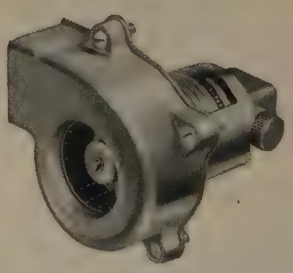
Ultra-Sensitive Relays

Operating on input powers of 40 to 1,000 microwatts, the Barber-Colman Micropositioner polarized relay is ideal for use as a differential relay in electronic plate circuits, a null detector in resistance bridge circuits, an amplifier in photoelectric circuits. Replaces several stages, simplifies various phases of electronic gear.



Reversible Small Motors

Shaded pole a-c type, up to 1/20 hp . . . adaptable to a variety of control circuits. Low-inertia rotors permitting rapid reversing and follow-up make these motors ideal for electronic circuits.



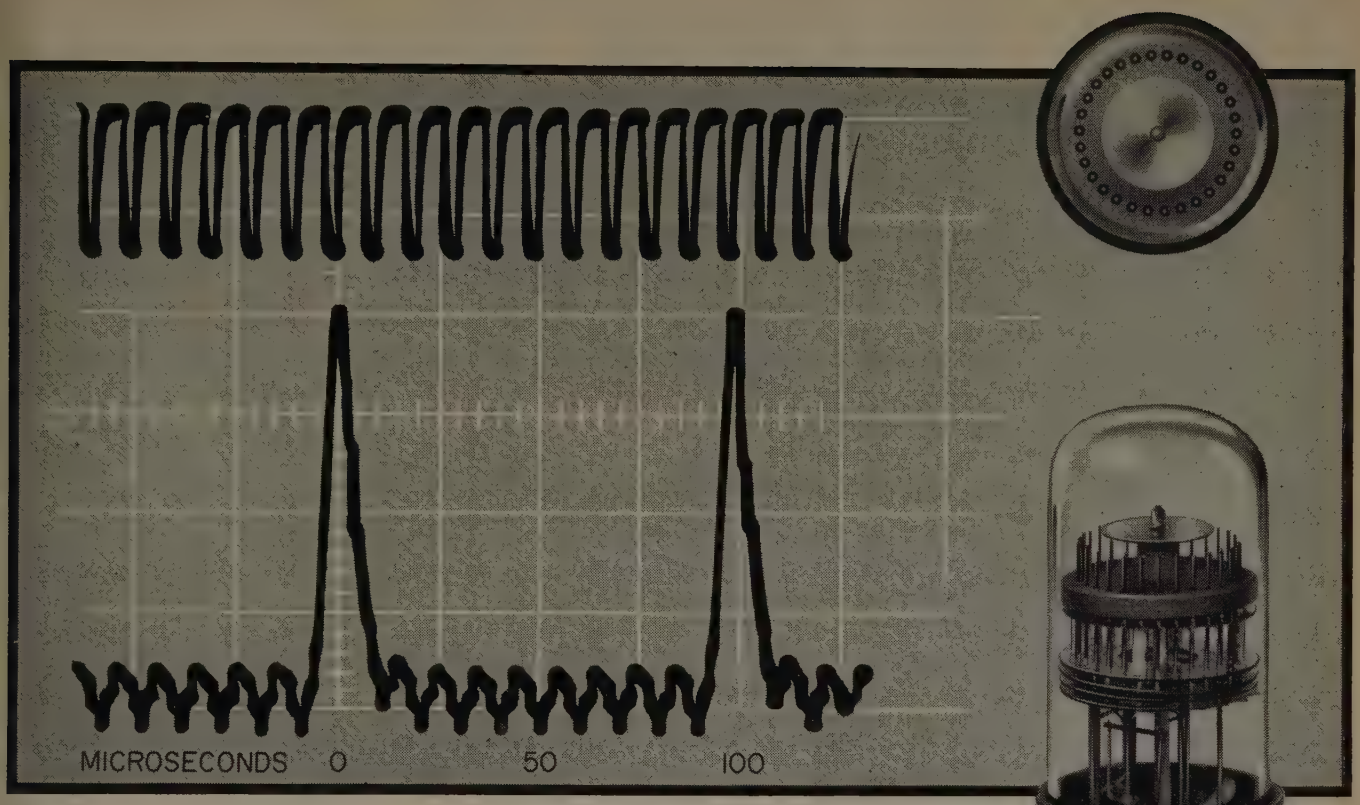
Small Motors with Blowers

In both a-c and d-c types with cooling fans or blowers for quick, dependable dissipation of heat from tubes, circuit components, and other equipment mounted in confined enclosures.

See demonstrated at
IRE SHOW — BOOTH 2240

BARBER-COLMAN COMPANY
Dept. O, 1856 Rock Street, Rockford, Illinois

Now—only from Sylvania



Zero cathode output at 100 KC. Short recovery time makes it possible to achieve 100 KC counting speed and respond reliably to random pulses such as those received from radiation detection devices.

NEW *HIGH SPEED* COUNTER TUBES

—wrap 100 KC counting circuits into a single envelope

Sylvania answers the designer's biggest need for high speed bi-directional counting. Now with these 100 KC tubes designers can minimize circuitry in counters requiring multiple stages and re-setting functions, work previously done with numerous vacuum tubes and neon-indicators.

These high speed counter tubes exhibit the same neon glow characteristics as the lower speed types. Thus it is possible to design a 100 KC stage into a counter and retain readout color uniformity on the instrument panel.

And they make it possible to design smaller, lighter, counter instruments at lower cost. Write for complete details. Address Department C32R.

Now, Sylvania is your leading source for both medium and high speed counter tubes

Type	Freq.	Output Cathodes	Base	Min. D.C. Supply Voltage	Max. Anode Current
6909	100KC	4(0,5,8,9)	Octal	400 V.	1.2 ma
6802	4KC	4(0,5,8,9)	Octal	400 V.	0.6 ma
6910	100KC	10	Duo Decal	400 V.	1.2 ma
6476	4KC	10	Duo Decal	400 V.	0.6 ma
6879	5KC	3(0,8,9)	7-pin	320 V.	0.8 ma

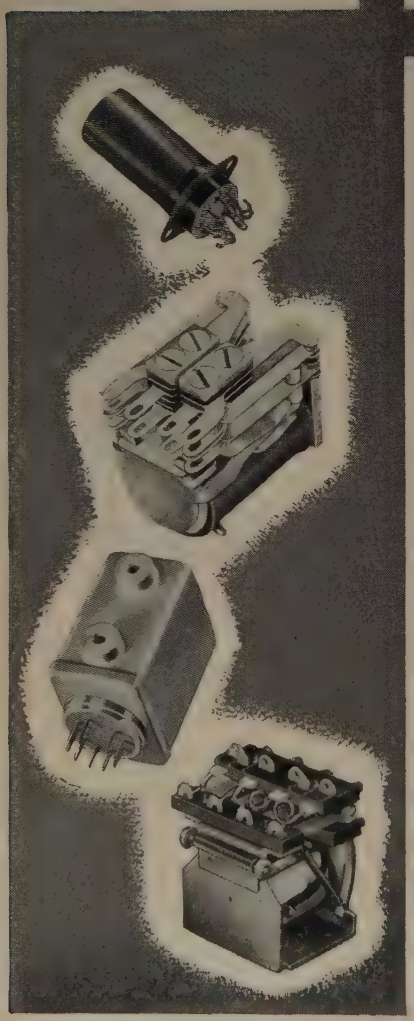
SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.
1740 Broadway, New York 19, N. Y.
In Canada: Sylvania Electric (Canada) Ltd.
Shell Tower Building, Montreal

LIGHTING • RADIO • TELEVISION • ELECTRONICS • ATOMIC ENERGY

THE RIGHT RELAY IS...

PRICE ELECTRIC CORP., FREDERICK, MD.
HUSKY RELAYS AND CONTROLS ®



A HUSKY RELAY!

Specify Husky Relays. You know you're getting the quality that comes from precision engineering. Every Husky Relay is thoroughly tested and inspected to insure that it meets the highest standards of performance.

Many varieties of relays for all types of application are included in the complete Husky line. We invite your inquiry for engineering review and recommendations.

Rely on a Husky Relay—the right relay for every job!

SEE US AT THE I.R.E. SHOW
BOOTH 2407
New York—March 18-21

Price Electric CORPORATION
FREDERICK, MARYLAND

Whom and What to See at the Radio Engineering Show

(Continued from page 378A)

Reeves Instrument Corp, Booths 1702-1710
215 East 91st St.
New York 28, N. Y.
Holton E. Harris, Joseph Grella, ▲ Philip I. Rafield, Herman E. Cousins, Melvin Kutchin, E. C. Frank, Gilbert Steinberg, Charles Lax, Ascher Chase
*Auto-control system for REAC "400" computers, *3-gyro stable platform, *Gyro test table, *1" gyro, *Size 11 resolver, complete *line of miniature servo breadboard parts, *sub-miniature magnetic clutch, REAC® computers, precision floated gyroscopes, high precision resolvers, servo mechanical parts, magnetic clutches and automation systems.

Reeves Soundcraft Corporation, Booth 1328
10 East 52nd St.
New York 22, N. Y.
Thomas J. Dempsey
Telemetering video-recording magnetic recording products, data processing.

Remington Rand
Div. of Sperry Rand Corp.
315 Fourth Ave.
New York 10, N. Y.
Booths 1301-1305
A. B. Fristia
Univac digital computer.

Resin Industries, Inc., Subsidiary The Borden Co., Booth 4011
P.O. Box 1589
Santa Barbara, Calif.
Allen W. Schmidt, Allan Stephens
*Hi-Heat 105 & 105A for Mil-I631C and Super Heat 125 for U.L. Applications.

Revere Corp. of America, Booth 4118
845 No. Colony Road
Wallingford, Conn.
G. W. Grace, Al Hills, ▲ P. R. de Bruyn
Low capacitance, high speed GLASWITCH relays with hermetically and individually sealed contacts. PERMACODE striped extruded teflon hook-up wire for permanent coding.

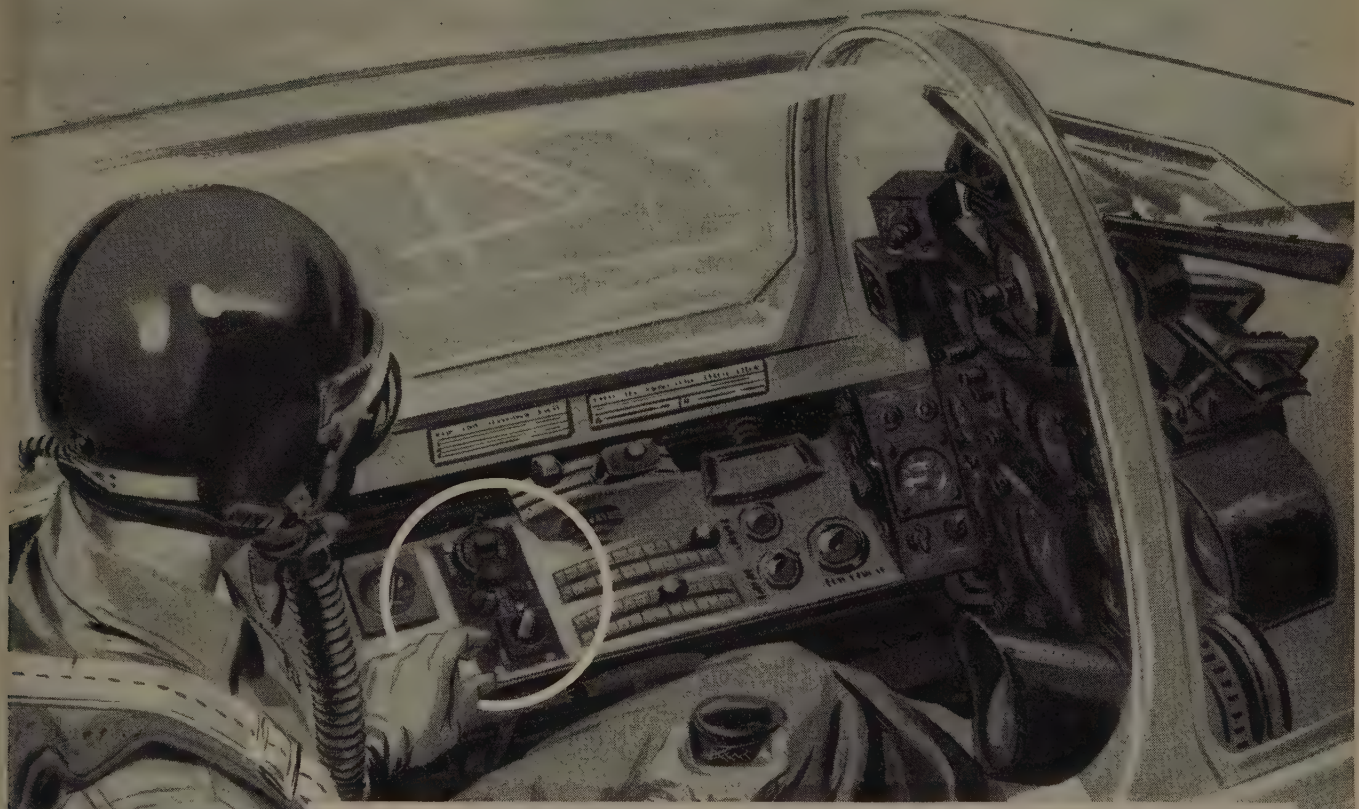
The Rex Corp., Booths 4304, 4305
Hayward Road
W. Acton, Mass.
H. E. Prouty, David Packard, Edward J. McIntyre, Norman R. Houghton, Richard A. Jenkins, James J. O'Keefe, Jerome B. Rice
Extruded and taped Teflon insulated wires Rexolite #1422 & #2200 UHF Cast Plastics, Telephone Wires & Cables, Trifluoromonochloroethylene insulated wires and cables, Microwall wires and cables, plastic insulated hook-up wires, control and intercom cables, rigid and flexible extrusions.

Rheem Manufacturing Co., Booth 2811
R&D Laboratories
9236 E. Hall Road
Downey, Calif.
G. L. Gillespie, M. B. Carpenter, C. E. Phillips, ▲ H. C. Bream
COLOR CODED SYSTEMS COMPONENTS
A full line of color-coded sub-miniature instrumentation equipment designed for airborne and special weapons systems application. Modular type construction includes amplifiers, voltage regulators, and power supplies.

(Continued on page 382A)

* Indicates new product.
▲ Indicates IRE member.

You can't shrink the pilot
...so *Admiral* shrinks the controls



New transceiver control box reduced to one-fifth former size

The cockpit of a modern fighter plane is packed as tight as a filling in a hollow tooth. As more and more electronic equipment is added to the plane's complement, each new device must fight for space on and behind the instrument panel or console. Now Admiral, maker of the famed AN/ARC27 transceiver, has designed a control box that "moves over" to make room for other needed equipment.

Heart of the new control is an ingenious "mechanical memory" drum that selects any one of 20 preset frequencies with a single knob. Another knob controls three coaxial switches designed by Admiral so the pilot can manually select any of the transceiver's 1750 frequencies. This single compact unit will be universally employed to replace any one of 15 currently used control box combinations. It occupies as little as one-fifth the space and also reduces weight up to 80%.

Here is another instance where Admiral initiated and perfected an important advance in the science of military electronics. Inquiries are invited regarding Admiral's capabilities and production capacity for electronic or electro-mechanical equipment.

Admiral®
CORPORATION
Government Laboratories Division, Chicago 47

RESEARCH • DEVELOPMENT • PRODUCTION
IN THE FIELDS OF:
COMMUNICATIONS UHF AND VHF • MILITARY TELEVISION • RADAR
RADAR BEACONS AND IFF • RADIAC • TELEMETERING
DISTANCE MEASURING • MISSILE GUIDANCE
CODERS AND DECODERS • CONSTANT DELAY LINES
TEST EQUIPMENT • ELECTRONIC COUNTERMEASURES

ENGINEERS: The wide scope of work in progress at Admiral creates challenging opportunities in the field of your choice. Write Director of Engineering and Research, Admiral Corporation, Chicago 47, Illinois.

TYPE 120-D

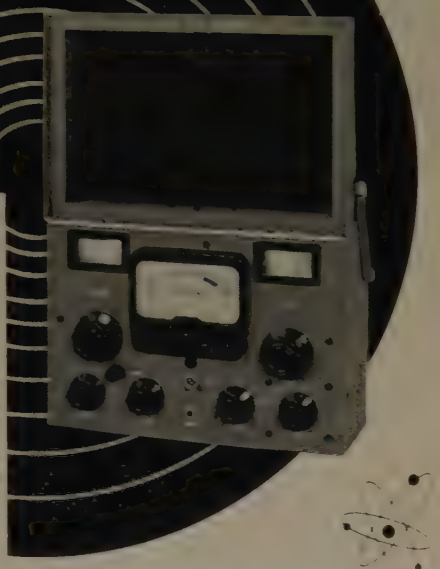
NEMS-CLARKE

FIELD INTENSITY METER

LIGHT WEIGHT
DIRECT READING
SELF-CONTAINED

A portable instrument for measuring the wide range of radio signal intensities from 540 to 1600 kc. Its range is from 10 microvolts to 10 volts per meter, making it equally effective for interference studies at low signal strengths and close-in measurements on high-power directional arrays.

Accuracy is assured by a calibration method that compensates for variations in tube characteristics and for voltage variations in the self-contained battery power supply. Operation is simple—measurements made rapidly—direct reading on all ranges—requires no charts or multiplication factors—no warm-up period necessary.



NEMS-CLARKE
Incorporated
919 JESUP-BLAIR DRIVE
SILVER SPRING, MARYLAND

For further information write Dept. K-4

TIC announces a dramatic achievement in vibration measurement



MODEL 501
VIBRATION
CALIBRATOR

- Rapid calibration of vibration pickups
- Non-contacting measurements, 20-20,000 micro-inches
- Single non-resonant probe covering 10 to 20,000 cps
- Field standardization against dial gauge
- Vibration waveform monitoring output

An extremely versatile Vibration Calibrator for direct displacement measurements of non-magnetic metals, utilizing surface diameters as small as 7/8". Also measures magnetic and non-metallic surfaces. Besides providing a convenient and rapid means of calibrating various types of vibration pickups, Model 501 is ideal for testing rotating shafts; measuring characteristics of microphone and speaker diaphragms; for metal-sorting operations, many other applications. Write for complete data to Dept. Q.

See the Model 501 demonstrated at the IRE Show, Booths 3406 and 3408.

TIC Tel-Instrument ELECTRONICS CORP.

728 GARDEN ST.
CARLSTADT, N. J.

Whom and What to See at the Radio Engineering Show

(Continued from page 380A)

Richards Electrocraft, Inc.
3739 N. Kedzie Avenue
Chicago 18, Illinois

Booth 3917

Stephen G. Richards, George Lewis, Bruce Trimble, Jules Bressler

See the New Push Button Switches and Shielded Vax. Standard line plugs, jacks, mic connectors, cord mounted jacks, adapters.

Richardson Co.
27 Lake St., Melrose Park, Ill.

Booth 1628

L. V. Comeford, Glen W. Neely, Ed. W. Ruehrwein, Paul Brown, Bob Wentland

New high "IR" cold punching laminate also copper-clad sheets, tubes, rods, also fabricated and molded parts . . . complying with NEMA, Federal and Military specifications.

The Riester & Thesmacher Co.
1526 W. 25th St.
Cleveland 13, Ohio

Booth 4203

M. A. Thesmacher, F. E. Elliott, C. D. Burt, Wm. Sasak

Specialists in engineered sheet metal enclosures, cabinets, chassis, etc. We work in all metals including steel, aluminum, stainless steel, copper and brass.

Rixon Electronics, Inc.
2414 Reedie Dr., Silver Springs, Md.

Booth 1725

Robert E. England



Mux-16 (AN/TCC-35)

RIXON MUX-16 (AN/TCC-35) A sixteen channel teletypewriter time division multiplex unit utilizing computor components and new packaging techniques.

Robertshaw Fulton Controls Co.
2040 East Main St.
Columbus 16, Ohio

Booth 2708

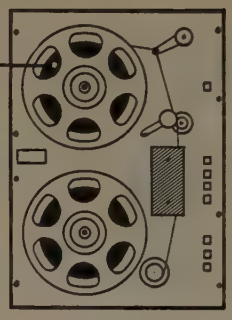
A. Unetic, F. C. McCloskey, L. R. Preslan

Complete line of sub-miniature switch actuators.

(Continued on page 384A)

HYCON EASTERN introduces

RAPID ACCESS IN ANALOG DATA REDUCTION SYSTEMS





Two companion units by Hycon Eastern provide automatic high-speed access to selected data in Ampex Recorders and similar multi-channel magnetic tape instrumentation systems.

For Tape Indexing

DIGITAL TIMING GENERATOR, Model 201, generates numerically coded timing signals which are recorded on the magnetic tape throughout the data recording periods, providing a precise digital index in terms of elapsed time. The Generator also visually displays the exact time in hours, minutes and seconds as illuminated digits.



For Tape Search

MAGNETIC TAPE SEARCH UNIT, Model 202, operates during data reduction periods. On the basis of time indices recorded on the tape by the Digital Timing Generator, this instrument automatically locates and selects for controlled playback the tape data included between a "sequence start time" and a "sequence end time" specified by panel dial settings. The time index is visually displayed as illuminated digits on a small separate panel which may be remotely located for convenience.

DESIGN FEATURES

TIMING INFORMATION occupies only a part of the available bandwidth on a magnetic tape channel . . . remaining bandwidth in timing channel may be used for other purposes; e.g. to record other digital or analog data, or as a voice channel.

TAPE SPEEDS of 60, 30, 15, 7½, 3¾ or 1⅞ inches per second may be used for recording. For playback, any one of these 6 speeds or a high-speed search rate may be used. Other speeds may be incorporated as required.

TIMING TRACK contains a combination of complete time numbers in hours, minutes, and seconds together with interpolation pulses so that time can be measured with a resolution of a few milliseconds.

ADDITIONAL SIGNALS for recording, recovery and display may be assigned to arbitrary control functions in the data system.

FORWARD OR REVERSE directions may be used for tape search at either the high-speed search rate or any one of the 6 normal record play back speeds.

MOUNTS in any RETMA standard 19" relay rack.

Write for Technical Bulletin TSG-O

HYCON EASTERN, INC.

75 Cambridge Parkway Dept. B Cambridge 42, Mass.

Affiliated with HYCON MFG. COMPANY, Pasadena, California

IRE SHOW
Booths 3038 & 3039

HIGH VOLTAGE

but no danger!



AC DIELECTRIC STRENGTH TESTER

- Conforms to ASTM D-149 and Federal Specification LP-406 Method 4031.
- Plug-in interchangeable test jigs for all ASTM tests.
- Automatic or manual increase of voltage.
- Completely interlocked for personnel safety.
- Self-contained test chamber.

MODEL	RANGE	PRICE
PA-5-152	15,000 V rms. 2KVA	1600.00
PA-5-155	15,000 V rms. 5KVA	1950.00
PA-5-252	25,000 V rms. 2KVA	1650.00
PA-5-255	25,000 V rms. 5KVA	2020.00
PA-5-502	50,000 V rms. 2KVA	1675.00
PA-5-505	50,000 V rms. 5KVA	2050.00
PA-50-1005	100,000 V rms. 5KVA	4500.00

ARC RESISTANCE TEST SET



- Conforms to ASTM D-495 and Federal Specification LP-406 Method 4011.2.
- Simplified operation, includes automatic stepping and timing.
- Improved electrode holder for test jig.
- Operable by unskilled personnel.

Price: Model ART-1 $1375.00

Write FOR COMPLETE ELECTRONIC TEST EQUIPMENT CATALOG . . .

Industrial Instruments INC.
89 Commerce Road, Cedar Grove, Essex County, N. J.

Whom and What to See at the Radio Engineering Show

(Continued from page 382A)

Robinson Aviation, Inc., Booths 2506, 2508
Teterboro Air Terminal
Teterboro, N. J.

Donald A. Bell, Frank E. Dal Lago, Robert J. Dickie, Daniel L. Elliot, Robert J. Fowski, Chester L. Gilbert, ▲ William A. Keetch, Harold C. Lawrence, Charles A. Lenge, Robert Sprung

*Isolation systems of Met-L-Flex; providing reliability of navigational, guidance and search systems. Shock and vibration environment dependably controlled while still accurately transmitting airframe attitudes and maneuvering information.

Roller-Smith Corp., Instrument Division, Booth 2743
1825 W. Market St.
Bethlehem, Pa.

James E. Miller

Electrical indicating instruments. Rotary switches, precision balances.

Rosán, Inc., Booth 4612
2901 West Coast Highway
Newport Beach, Calif.

J. Wright, Jr., A. Redlitz, M. Seddon, Jr.

Rosán press nuts are "tailor made" for the solution of fastening problems in the electronics industry. See the complete Rosán line of threaded fasteners.

Rotating Components, Inc., Booth 3920
267 Green Street
Brooklyn 22, New York

Nicholas F. Giarra, S. I. Gootnick, Arthur G. Miller, James H. Mills

*Compact plug-in cooling cabinet. Precision AC motors, blowers, fans, servos, generators, gearmotors. 1/1000-1/6 horsepower in wide range of temperatures, frequencies, voltages. MIL specs.

Rotron Mfg. Co., Booths 2334-2336
7-9 Schoonmaker Lane
Woodstock, N. Y.

▲ J. C. van Rijn, D. Carlson, W. W. Bielock, Jr., W. L. Sly, P. S. Lyon, A. Gran

"Aximax family consisting of 3 sizes of miniature vaneaxial fans." We will feature a complete line of small fans and blowers for cooling electronic gear to include axial flow fans, centrifugal blowers inverted and regular, radial wheel and multi-stage blowers for either large air volume or pressure building applications. *Aximax I, *Aximax III, *Model L multi-stage Blower, *RF Cooling Panel, and the *DFE 50 or 420 cps dual frequency 4" fan.

Royal Electric Corp.
Pawtucket, R. I.

Booths 2510-2625

A. A. Segal, J. L. Brodsky, W. C. Murray, H. Lubars, H. Singer, H. R. Studer, E. Giordano, W. V. Costello

Super high temperature cable. Teflon jacketed cable. Teflon dimensionally stable cable. Miniature non-microphonic cable.

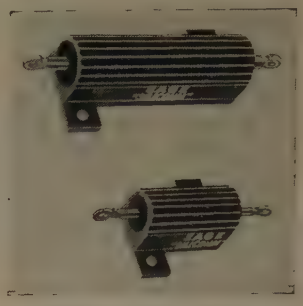
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(Continued on page 386A)

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(for collector current of 2 amps.)

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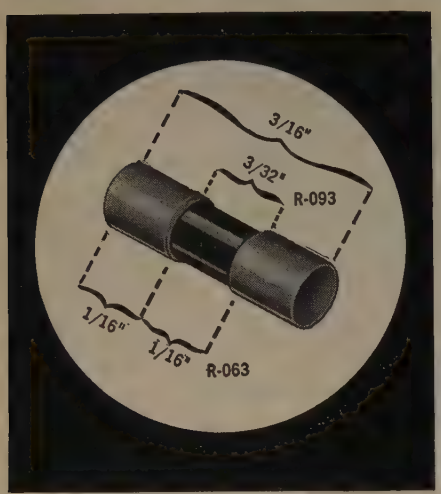
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Pure resistive elements

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Wattage: ¼ watt continuous duty at 25 degrees centigrade
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Terminals: Tinned sections 1/16 inch long
Film Length: Type R-063 — 1/16 inch
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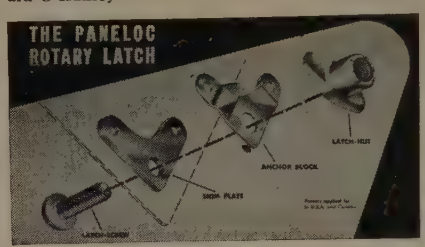
Whom and What to See at the Radio Engineering Show

(Continued from page 384A)

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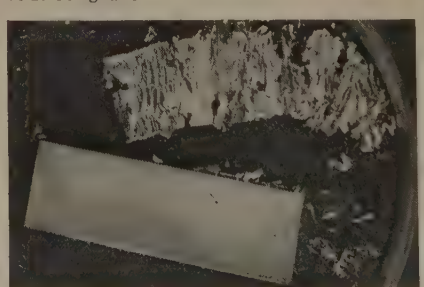


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Morton D. Brozinsky
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(Continued on page 388A)



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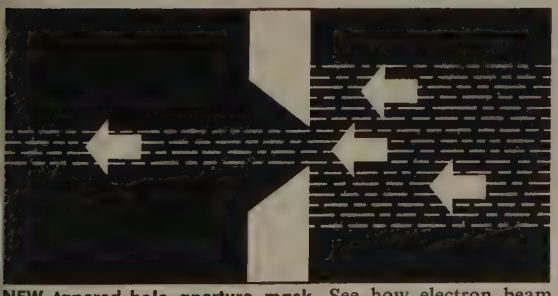
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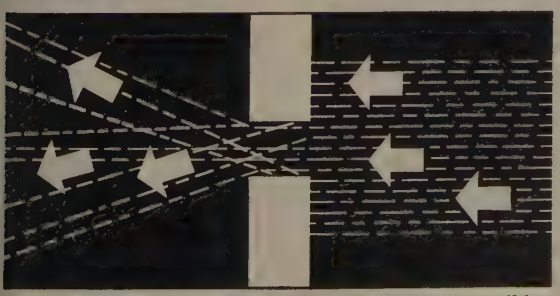


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New tapered-hole aperture mask reduces beam diffusion . . . minimizes false color . . . can be used in present design picture tubes



NEW tapered-hole aperture mask. See how electron beam passes through hole without diffusion. Hole dimensions: .010 in. small diameter; .015 in. large diameter. There are nearly 500,000 of these holes in each mask—all controlled to close tolerance.



OLD cylindrical hole aperture mask. Electrons striking aperture walls are scattered over several dots.

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These new aperture masks demonstrate how accurate and to what close tolerances Superior Tube can fabricate metal components. For complete information, write for Data Memo No. 5. Superior Tube Company, 2506 Germantown Ave., Norristown, Pa.

**Manufactured by Superior Tube Co. under license from Buckbee Mears, Co., St. Paul, Minn.*

Other parts Superior Tube makes for use in color TV receivers include three different types of disc cathodes (miniature, narrow neck and standard), seamless anodes, and a complete line of sleeve-type cathodes. Superior Tube is the world's largest independent supplier of cathodes for use in electron tubes.

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Johnson & Hoffman Mfg. Corp., Mineola, N.Y.—an affiliated company making precision metal stampings and deep-drawn parts such as those used in the electron guns that go with this new cathode.

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Whom and What to See at the Radio Engineering Show

(Continued from page 386A)

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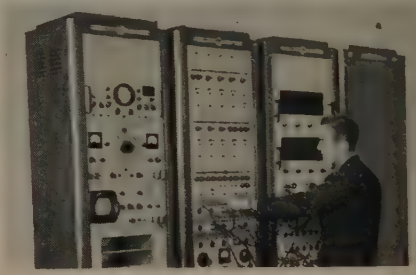


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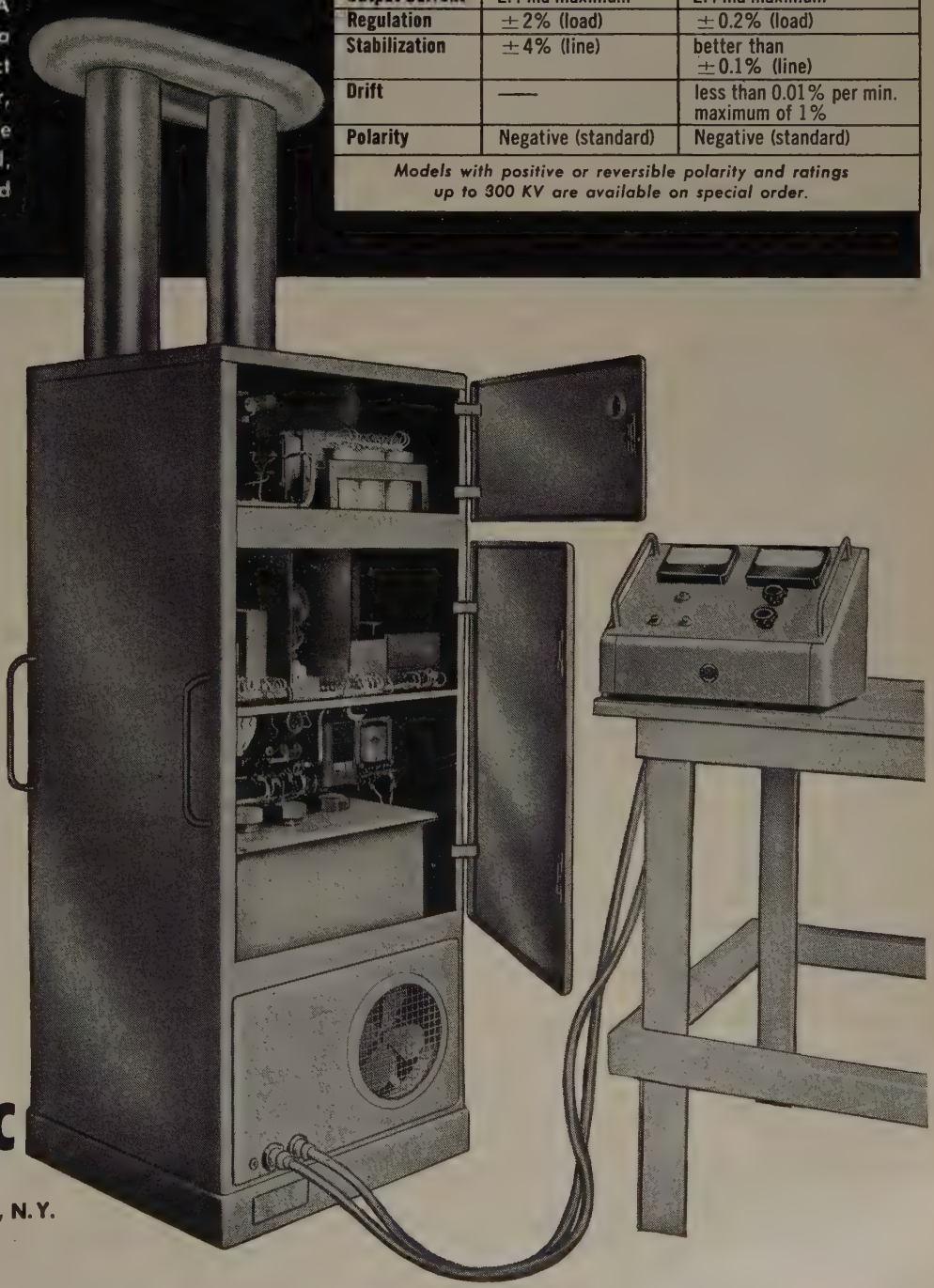
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Introducing a new Series of **REGULATED** power supplies to add to the ever-expanding BETA line of safe and reliable high voltage equipment. The new BETA Series 6000 features a rugged, light and compact **ELECTROSTATIC** generator, and is ideal for high voltage research in the electrical, electronic, radiological and nuclear industries.

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(Continued from page 388A)

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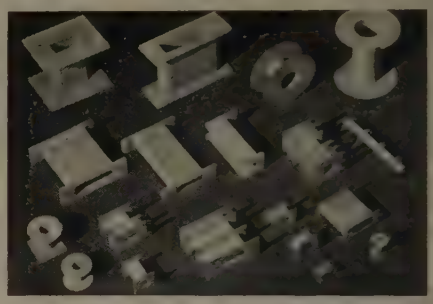
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FREQUENCY RANGE Sine Waves: 500 cps down to 1 cycle every 33 minutes. Square Waves and Pulses: 100 microsecs to 1,000 secs. Ramps and Sawtooths: 1 millisec to 1,000 secs.

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OUTPUT CURRENT Up to 5 ma. load current may be drawn.

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(Continued on page 392A)

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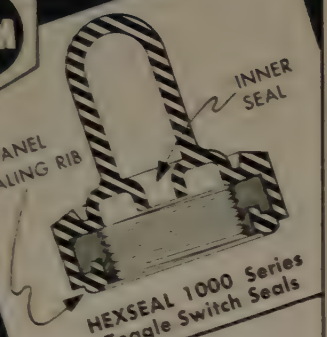
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APM



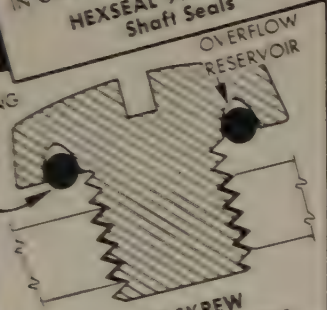
HEXSEAL 1000 Series
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Whom and What to See at the Radio Engineering Show

(Continued from page 390A)

Herman H. Smith, Inc., Booth 3903
2326 Nostrand Avenue
Brooklyn 10, N.Y.

Ira L. Landis, Sheldon Sackman, Nat Kopf

Phone Tip and Banana Plugs and Jacks: Multi Purpose Binding Posts; Test Leads; Toggle Switches; Terminal Strips and Terminal Boards; Alligator Clips and varied Electronic Components.

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Booths 2817-2819

▲ H. U. Hjermstad, N. P. Marshall, ▲ R. H. Schlote, H. H. Maass, H. J. Lutz, J. P. Kennedy, ▲ J. T. Keefe

Five new ratings of Constant Voltage Filament Transformers; also constant voltage transformers, regulated electronic power transformers, regulated dc power supplies, adjustable, regulated ac and dc voltage supplies, and related products.

Solartron, Inc., Booth 2009
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John Bolton, Mr. Ridgewell, Ian Lynas, Geoffrey Rigby

The world's foremost servo test equipment accelerates frequency response testing. Complete discrimination against noise and harmonics. May be used with carrier type, mechanical, hydraulic servos, etc.

Sorensen & Co., Inc.
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(Continued on page 394A)

First Floor—Equipment
Second Floor—Component Parts
Third Floor—Instruments & Components
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KLYSTRON MOUNTS

S band. Type N output. Tuneable over entire band. For Shepard type tube i.e. 726. w/socket & tube clamp. Mfg. GE. New. $15.00.
X band. UG39 flange output. Completely encl. & shielded. For 2K25 type Shepard tube. Incl. varia. rough attenuator, socket. Mfg. PRD. New. $67.50.
K band. 2K50 output cplg. w/90 deg. H bend. New. $10.50.



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S band. Type N. ⅜ coax. Tunes for xtal match. Avail. negative or positive output. New. $15.00 each.

TRANSITIONS

S band. Type N output. RG48 (3 x 1½") input. New. $35.00.
X band. Type N output. RG52 (1 x ½") input. New. $15.00.
TAPER. RG51 to RG52 (1¼ x ⅝" to 1 x ½") Smooth Electroform. Standard Flanges. New. $16.50.

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X band. 3 types. a) uni-directional CG-176/AP. b) bi-directional. c) cross guide mfg. Airtron. All apx. 20db. All RG52 guide. w/standard flanges. New. $15.00 each.
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FILTER CAVITY F-28/APN-19. 2700-2900 1.5 db max. loss at CTR. Freq. overband. Varia. insert loss. New. $37.50.
RADAR BEACON RCVR R-149/APN-19. Comprises microwave RF crystal detector, video amplifier stages, duty cycle limiter, blocking osc, control circuits. Operates on 2 channels in 2600 to 3400 mc region with band width of 300 mc. when F-28 (above) is not used. In pressurized housing 10" lg. 6" dia. Excellent condition.
$125.00 each.
POWER SUPPLY DY30/APN-19. (for above) includes Bendix dynamoter DA-31A input 19.5v, output 360v60ma, 100v10ma fully regulated. Shock mounted.
As new. $44.50.

TS46/AP FREQUENCY METER complete 3000mc band coverage with accuracy of .5mc relative, absolute plus and minus 3mc. 200 microamp. meter. Micrometer adjust. Equal to TS-117. New $35.00.
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MINIATURE 60MC IF STRIP uses 6 ea. 6AK5 tubes, with synchronous single tuned interstage coupling networks realizing an overall gain of 100db for a band width of 2mc. Weight 9 ounces. $12.50.
"BNC" COAXIAL SWITCH single pole double throw. New $6.50.
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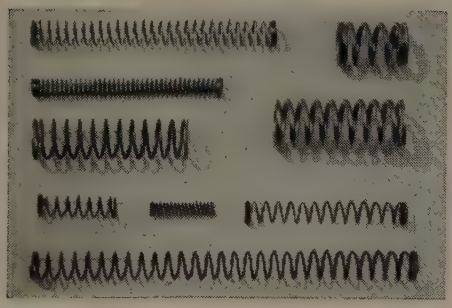
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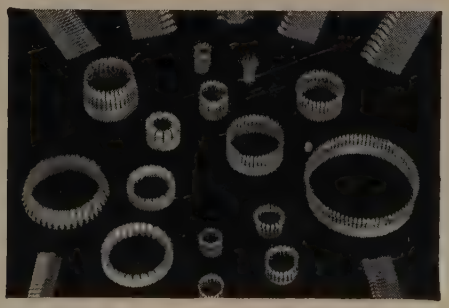
STRIP SPRINGS

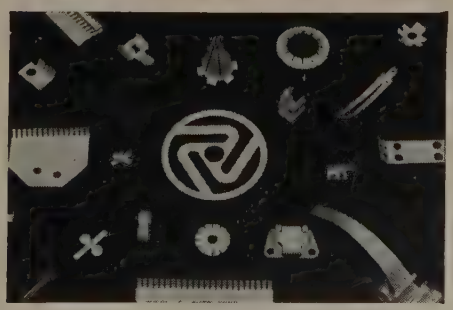
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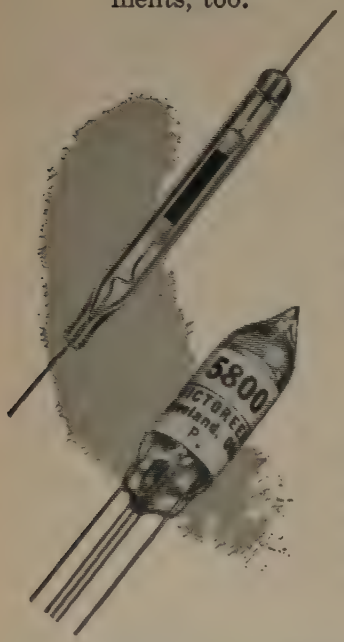
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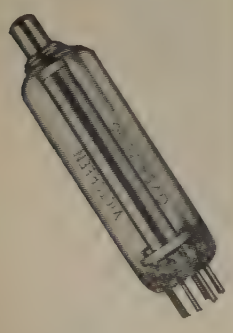
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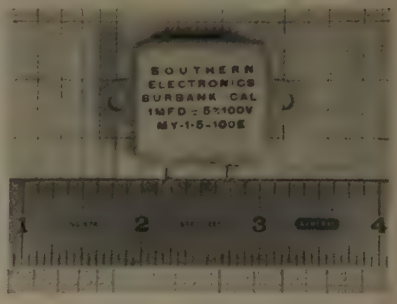
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Whom and What to See at the Radio Engineering Show

(Continued from page 392A)

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Booth 2309

Geo. E. Gansell, ▲ Norman Schwartz



Plastic Capacitors

The smallest case sizes available for Ultra High Precision Plastic Capacitors. Reliability plus wide variety of miniature cans.

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Specific Products, Booth 1108
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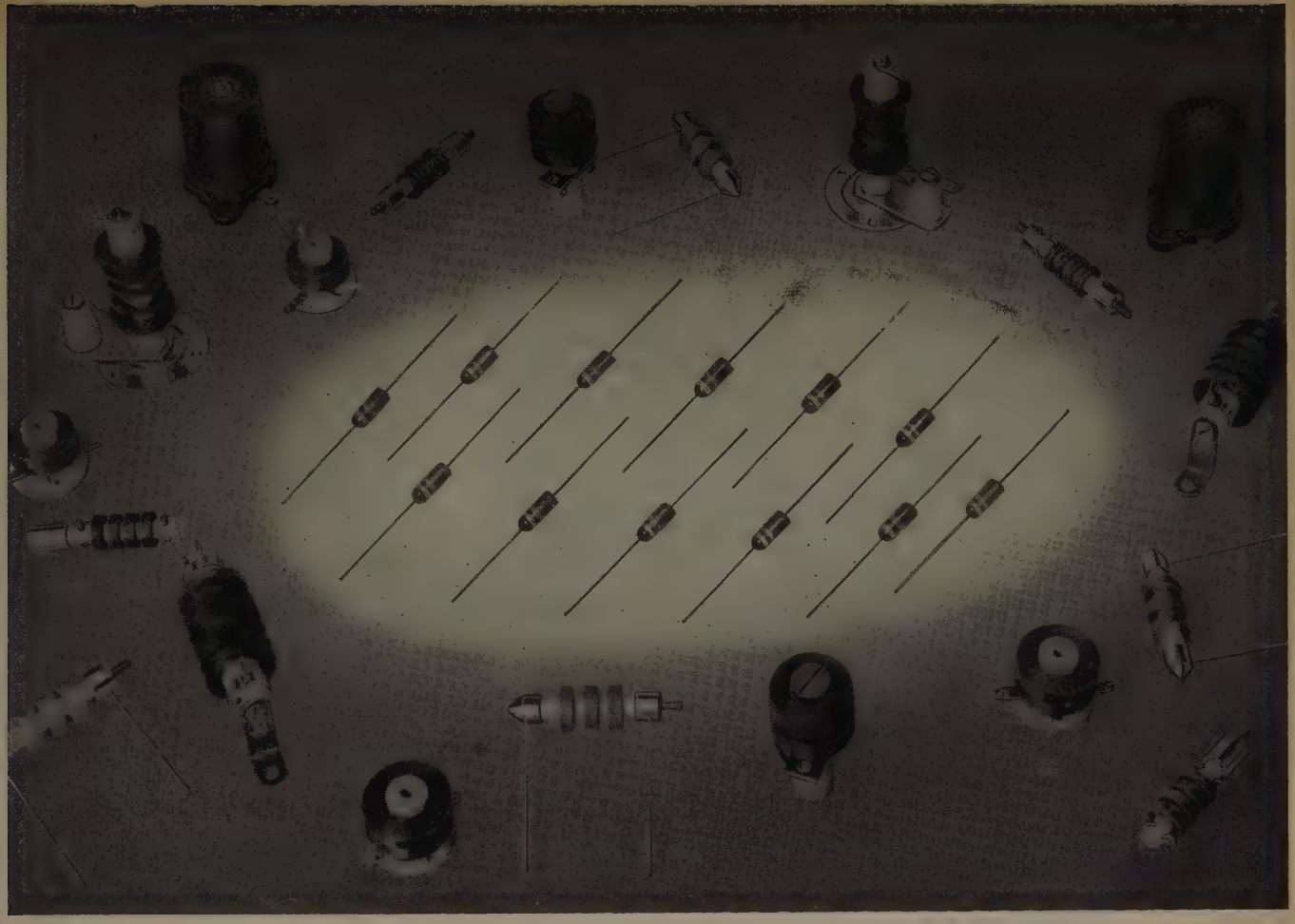
WWV Receiver Model SR-7. A compact sensitive unit designed specifically for the reception of WWV. Model WWVC frequency comparator.

Spectrol Electronics Div., Carrier Corp., Booth 1726
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San Gabriel, Calif.

▲ Robert C. Chase, ▲ Frank C. Braugh, Gene A. Young

Miniature Precision ten-turn Model 500 Potentiometers. Complete Line of Single-turn Precision Potentiometers. Precision three-turn and ten-turn Potentiometers.

(Continued on page 396A)



Encapsulated Inductances

Millen DESIGNED for APPLICATION encapsulated coils provide another advance in the r-f inductor field. Modern application requires miniature, heat and cold resistant, hermetically sealed, and abrasion resistant r-f inductor assemblies. The James Millen Manufacturing Company has pioneered many advances in the r-f inductor field, including the now standard 4 pi r-f choke, the axial lead r-f choke, and the miniature r-f choke. Developments have now made possible another advance, the No. 34301 and No. J301 encapsulated inductors—hermetically sealed—miniature size. Ambient temperature minus 55 degrees to plus 100 degrees C.

NO. J301 MINIATURE ENCAPSULATED INDUCTANCES

DESIGNED for APPLICATION miniature inductances are: extremely small (see table at right)—hermetically sealed—wound on axial lead Carbonyl cores—color coded. Coils are available in RETMA standard values plus 25, 50, 150, 250, 350, 500, and 2500 microhenries. Coils are three layer solenoids up to 350 microhenries. From 360 to 2500 microhenries coils are pi-wound. Current rating 50 to 600 milliamperes depending on coil size. Inductance ± 5%. Special coils on order.

NO. 34301 STANDARD ENCAPSULATED INDUCTANCES

Encapsulated DESIGNED for APPLICATION axial lead phenolic form r-f inductances. Hermetically sealed—heat resistant—abrasion proof—color coded. 1 to 350 microhenries available in RETMA standard values plus 25, 50, 150, 250, and 350 microhenries. Inductance ± 5%. Values available in same progression as J301 coils listed in the table at the right. Solenoid winding for 1 to 15 microhenries. Universal pi winding from 20 microhenries to 350 microhenries. Current rating 250 to 1500 milliamperes, depending on coil size. Ambient temperature range—minus 55 degrees to plus 100 degrees Centigrade. Size: 3/8 inches diameter × 7/8 inches long. Special coils on order.

COIL NUMBER	INDUCTANCE MICROHENRIES	DIAMETER INCHES	LENGTH INCHES
J301-25	25	3/16	9/16
J301-33	33	3/16	9/16
J301-47	47	3/16	9/16
J301-50	50	3/16	9/16
J301-82	82	3/16	9/16
J301-100	100	3/16	9/16
J301-120	120	3/16	9/16
J301-150	150	3/16	9/16
J301-200	200	3/16	9/16
J301-220	220	3/16	9/16
J301-250	250	3/16	9/16
J301-300	300	3/16	9/16
J301-330	330	3/16	9/16
J301-350	350	3/16	9/16
J301-360	360	7/32	5/8
J301-390	390	7/32	5/8
J301-430	430	7/32	5/8
J301-470	470	1/4	11/16
J301-500	500	1/4	11/16
J301-510	510	1/4	11/16
J301-560	560	1/4	11/16
J301-620	620	1/4	11/16
J301-680	680	9/32	3/4
J301-750	750	9/32	3/4
J301-820	820	9/32	3/4
J301-910	910	9/32	3/4
J301-1000	1000	9/32	3/4
J301-1200	1200	5/16	13/16
J301-1300	1300	5/16	13/16
J301-1500	1500	5/16	13/16
J301-1800	1800	5/16	13/16
J301-2000	2000	3/8	7/8
J301-2200	2200	3/8	7/8
J301-2400	2400	3/8	7/8
J301-2500	2500	3/8	7/8

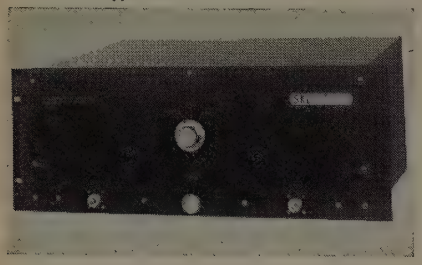
JAMES MILLEN MFG. CO., INC.
MAIN OFFICE AND FACTORY
MALDEN, MASSACHUSETTS, U.S.A.

Whom and What to See at the Radio Engineering Show

(Continued from page 394A)

Spencer-Kennedy Labs., Inc.
1320 Soldiers Field Road
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Booths 3502-3504

J. B. Sullivan, ▲L. C. Smith, V. Pokorny, ▲F. Kennedy, ▲T. Randell

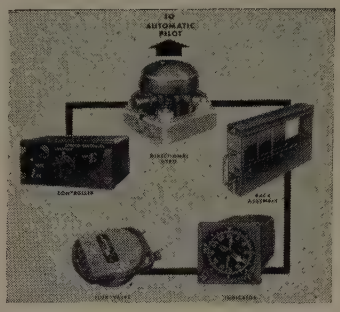


Model 206 Wideband Amplifier

320 Mc wideband amplifier for fast rise pulses, with nine possible combinations of response characteristics and output modes, including gradual roll-off and 100 volt output.

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Aeronautical Equipment Div.
Great Neck, L. I., N. Y.
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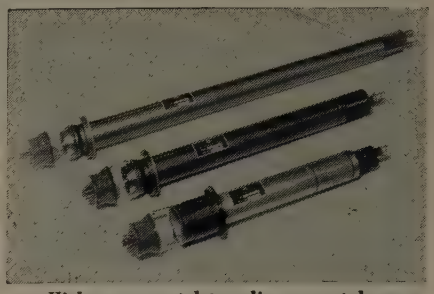
F. Conace, W. F. Aeri, W. W. Downs, T. W. Cooley, R. Carlton



Transistorized C-11 Gyroson® Compass System.

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Great Neck, L. I., N. Y.
Booths 1416-1418

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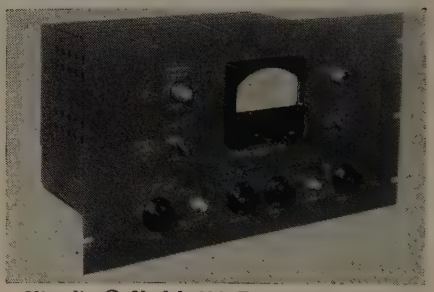


High-power metal traveling wave tubes

Klystron amplifiers and oscillators, reflex klystrons, high-power metal traveling wave tubes for radar transmitters, low-power traveling wave tubes for special applications.

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Complete information on the firms providing any specific product or service is available from the information booth on the first floor (Booth 1113).

A complete list of all registrants, brought up to date twice daily, is posted on the west wall at the back of the first floor. This list includes company affiliations and local hotel, if any.



Sprague Electric Co.
235 Marshall Street
North Adams, Mass.

Booths 2416-2422

Sid Chertok

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E. S. White, D. H. Locke, A. E. Bishop

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PA-1 Adjust-A-Volt Variable Transformer. Smallest Packaged Unit on the Market. Indispensable Laboratory Item.

(Continued on page 398A)

Kepco

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for Transistors • Strain Gages
Relays • Filament Power

MODEL	Volts	Current	Regulation Line 105-125	Regulation Load 0-Max.	Ripple	Recovery Time*	Stability For 8 Hours	Output Impedance DC-20 ∿	Output Impedance 20∼—100 KC	Dimensions W	Dimensions H	Dimensions D	Price
2600	0-60	0-2 Amp.	5 Mv.	5 Mv.	1 Mv.	50 μ sec.	10 Mv.	0.002 Ω	0.0005Ω	19″	10½″	17″	$690
2650	0-60	0-5 Amp.	5 Mv.	5 Mv.	1 Mv.	50 μ sec.	10 Mv.	0.001 Ω	0.0002Ω	22½″	28″	19″	$1190

Good stability
Fast recovery time
Low output impedance
Excellent regulation
Low ripple

POWER REQUIREMENTS: 105-125 volts, 60 cycles.
FUSE PROTECTION: Input and output fuses on front panel. Time delay relay is included to prevent unregulated voltage from appearing at the output terminations.

OUTPUT TERMINATIONS: DC terminals are clearly marked on the front panel. Either positive or negative terminal of the supply may be grounded. DC terminals are isolated from the chassis. A binding post is available for connecting to the chassis. All terminals are also brought out at the rear of the unit. Two terminals are mounted at the rear of the chassis to provide for picking up the error signal directly at the load. This connection compensates for the voltage drop in the wires (and ammeter) connecting the power supply to the load.

METERS: Ammeter: 0-2 amperes, 4" rectangular for Model 2600
0-5 amperes, 4" rectangular for Model 2650
Voltmeter: 0-60 volts, 4" rectangular

CONTROLS: Power on-off switch, DC on-off switch, remote error signal on-off switch, coarse and fine voltage controls. The coarse voltage control is a ten turn potentiometer which varies the voltage from 0-60 volts. The fine voltage control is a ten turn potentiometer which varies the voltage 1 volt. The voltage divider network allows a 61 volt variation in output voltage.

*Recovery time is less than 50 microseconds. The excursion in the output voltage during the recovery period is less than 50 millivolts for line fluctuations from 105-125 volts or load variations from 0-to maximum current.



FOR COMPLETE LINE
WRITE FOR CAT. B-568

KEPCO LABORATORIES, INC.

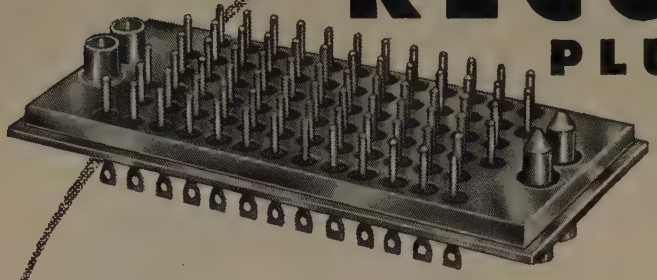
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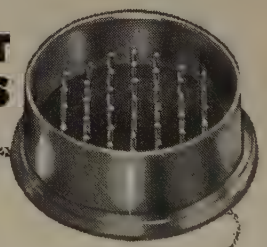
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Whom and What to See at the Radio Engineering Show

(Continued from page 396A)

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Star Expansion Products Co., Booth 4504
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State Labs., Inc., Booth 3939
649 Broadway
New York 12, N. Y.
See: Ericcson Corp.
Charles A. Tepper, ▲ Sture Edsman, Martin F. Schuster, Mark Schindler, Ira Becker, Nicholas J. DeSalvo, Irwin Feinstein, A. Meadows

Tube Types

5847/404A	6927/6J6L	18AK5	6760
5842/417A	6928/6AQ51	18AQ5	6761
5591/403B	6028/408A	18C51	
2C51/396A	407A	18J6	

Herman D. Steel, Booth 4034
See: Swiss Jewel Co.

Sterling Precision Corp., Instrument Division, Booth 1621
34-17 Lawrence St.
Flushing 54, N. Y.
William C. Okulski
Servo gear trains, computer components.

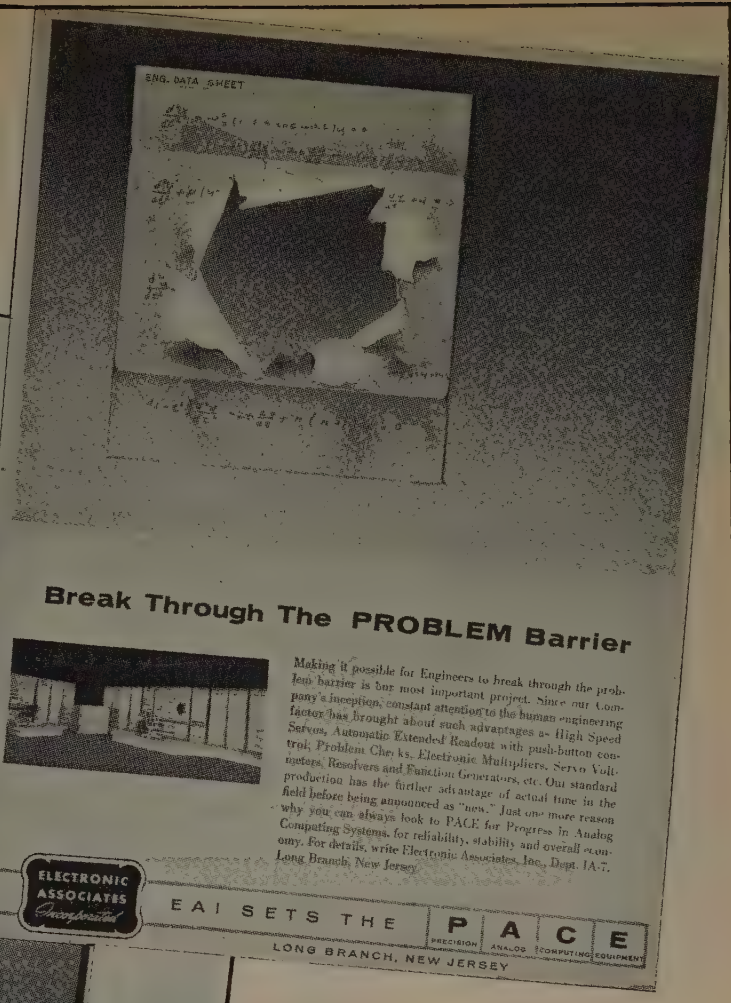
Sterling Transformer Corp., Booth 2121
297 North 7th St.
Brooklyn 11, New York
▲ Joel J. Sterling, ▲ Victor Gross, Ed Polen
TRANSFORMERS AND CHOKES: Aircraft, Military and Industrial; Power, Audio, Filter Chokes, Class H molded and open transformers. Transistor & R-F transformers. Custom Transformers.

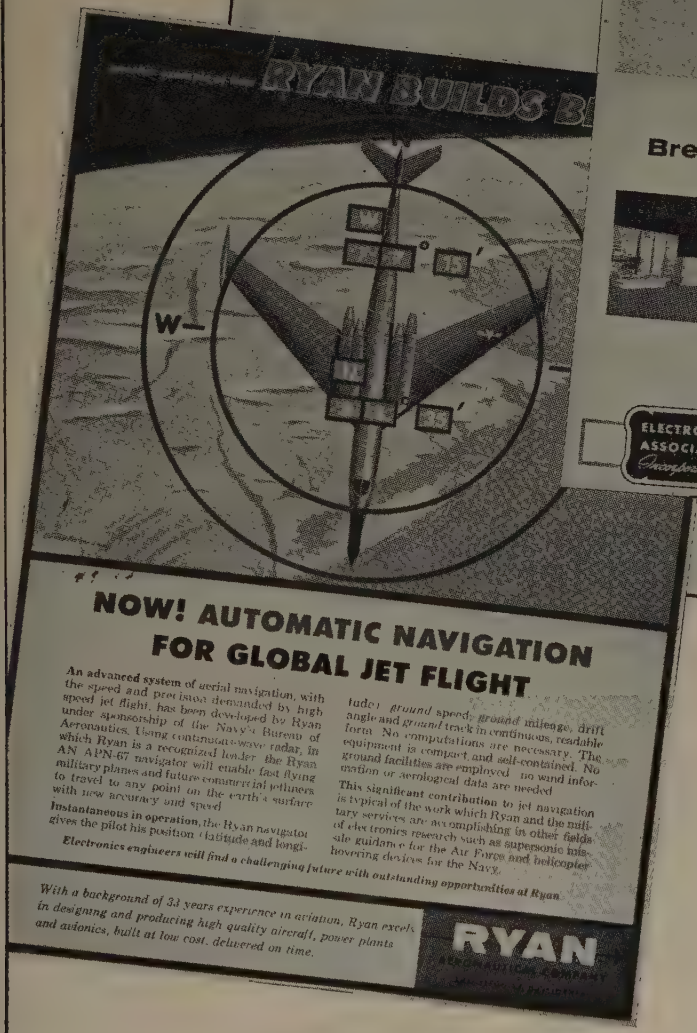
Stevens-Arnold Inc., Booth 2937
7 Elkins Street
S. Boston 27, Mass.
Ezra Stevens
Choppers, Relays.

Stevens Mfg. Co., Inc.
P. O. Box 1007
Mansfield, Ohio
Booth 2340
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George Stevens Mfg. Co.
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Booths 4213, 4220
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(Continued on page 400A)





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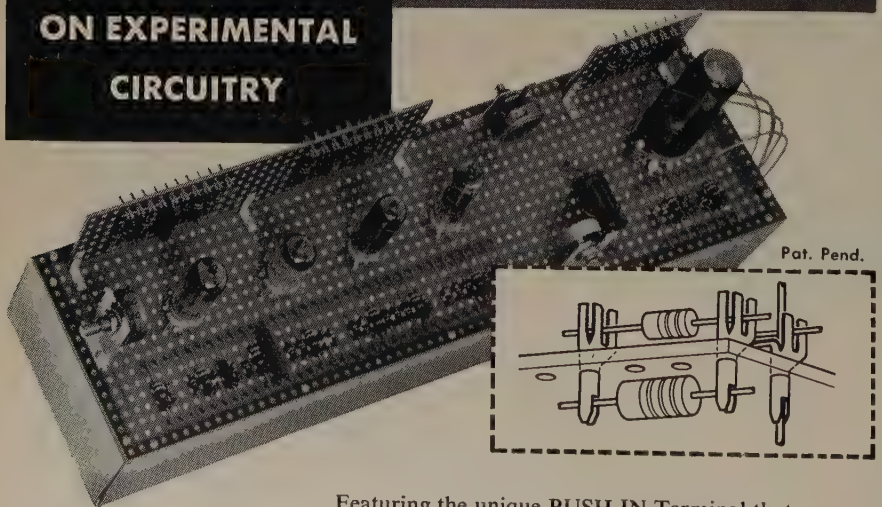
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(Continued from page 398A)

Stewart Stamping Co.
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Yonkers 4, N. Y.

Booth 4039

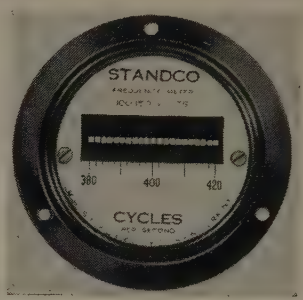
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*Vacuum Aluminizer convertible for aluminizing color TV face plates and black-white tubes will be shown in operation along with operating tabletting machine and supporting display of Tabletting, Plastics and High Vacuum Equipment for the Electronics Industry.

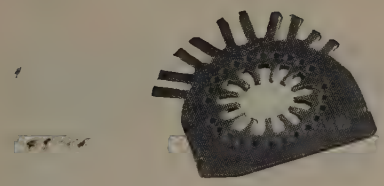
(Continued on page 402A)

The Stromberg-Carlson "Pagemaster" will be used by IRE Show Management. See it in action at Stromberg-Carlson Booths 3411-3413



High "IR" Cold-punching Laminate
INSUROK® XT-896

by Richardson

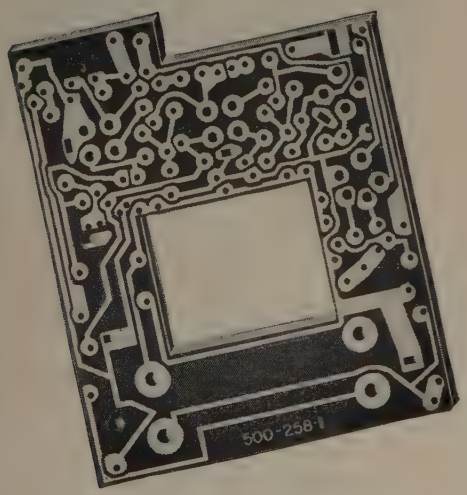


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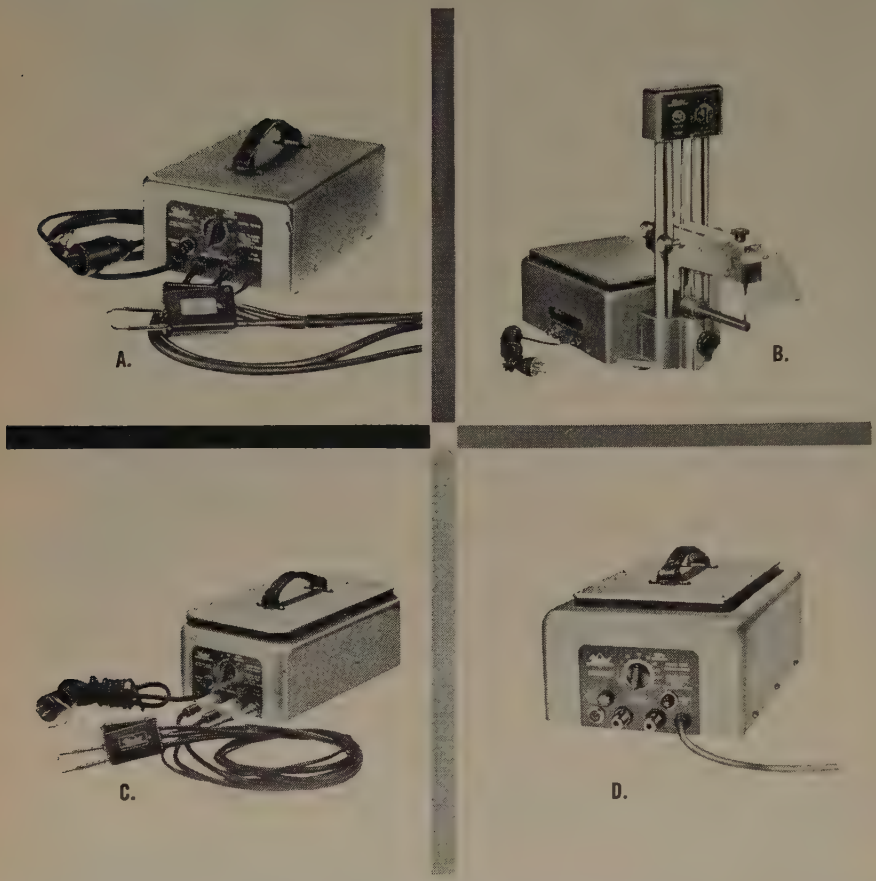
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1015	.0005 to .020	.0002 to .060	.0003 to .010	.0002 to .030
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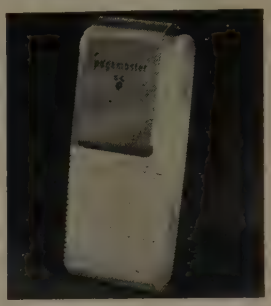
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Whom and What to See at the Radio Engineering Show

(Continued from page 400A)

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Booths 3411-3413

Roy Wunsch, Joseph Tondat, William Lucas, Guy Nixon, Harold Sager, Howard Gleason

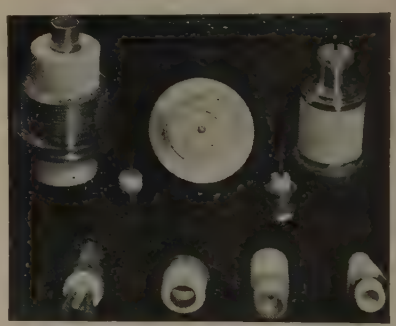


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(Continued on page 404A)

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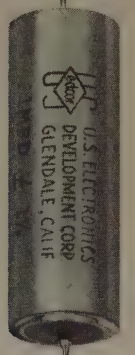
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HIGH *insulation resistance!*

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For precision, high-stability applications—complete variety of standard tubular types—all sizes, ratings and mountings!



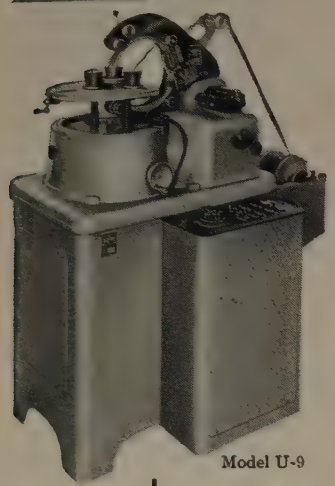
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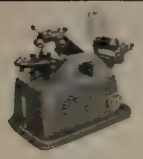
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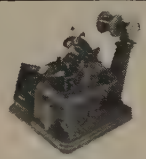
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Whom and What to See at the Radio Engineering Show

(Continued from page 402A)

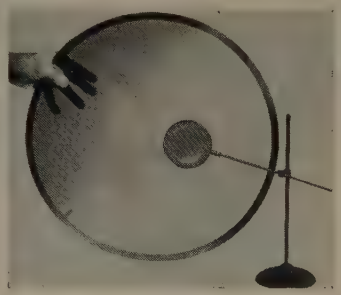
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(Continued on page 406A)

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Three-Axis Simulator gives accelerations of 40,000 deg/sec^2 in roll, 8,000 deg/sec^2 in yaw, and 20,000 deg/sec^2 in pitch. Dynamic Altitude Simulator has frequency response of 10 cps and bandwidth ±700 ft in altitude.

LOG-LINEAR AMPLIFIER

Designed for use in antenna pattern recording systems, the Logarithmic Linear Amplifier permits the use of conventional recording meters in plotting log functions on a linear scale. The input provides bias current for bolometer operation and will also accommodate crystal detectors.

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X-BAND ANTENNA-PATTERN TRANSMITTER

RADOME BORESIGHT-ERROR MEASURING EQUIPMENT

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Complementing this group of men is a modern plant containing up-to-the-moment facilities for manufacturing operations ranging from metal fabrication to assembly and final test.

Possibly this group can be of assistance in some of your production problems. Inquiries concerning design, development, manufacturing, or any combination, will receive careful attention.

Engineers: Career Opportunities are currently open.

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Agents in Principal Electronic Manufacturing Areas
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Whom and What to See at the Radio Engineering Show

(Continued from page 400A)

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Dr. H. Marey, B. Cahill, ▲ G. Harris



Miniature push-pull yoke, Military and special yokes. Focus coils for difficult problems. Application Engineering.

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Communications Systems Engineering, Automation Equipment, Data Transmission and Nuclear Products.

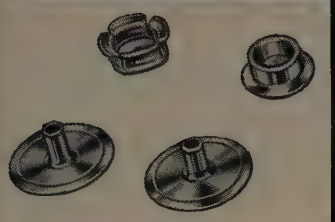
Technicraft Labs., Inc., Booth 3810
Thomaston-Waterbury Rd.
Thomaston, Conn.

George R. Houk, Kenneth Jefferies, Morris H. Wood, F .T. Eddy

*Double Ridge Waveguide and Components for the frequency range 2 to 5 KMC/s. Designated as D-37, it has a maximum loss of 0.04 db/ft. Also bendable and twistable flexible Waveguide, Rigid Bends and Twists and Waveguide-to-Coax Adapters which can be used with Type N, Type C or Type LC coaxial connectors.

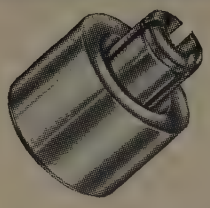
(Continued on page 408A)

Tailor-Made Fasteners in Volume Quantities



MINIATURE BATTERY CONNECTORS

For use with small "B" batteries; afford quick and positive polarized electrical connections and worthwhile space savings on small electronic equipment.

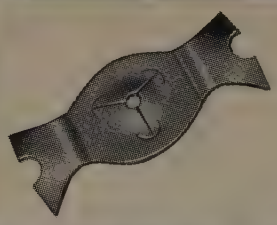


POLYETHYLENE MOUNTING FOOT

No mar no scratch glide for use on TV receivers, record changers and small appliances. Assembles into round hole in either wood or metal cabinets.

FISHTAIL RATCHET PLATE

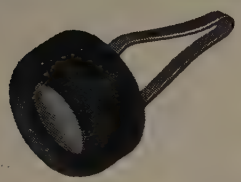
Made in a wide range of sizes to hold on smooth metal, die-cast or plastic studs. For use on refrigerators, radio cabinets, washing machines and other products to hold medallions, name plates, etc.



VIBRATOR GROUNDING FASTENERS

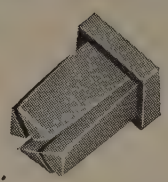
Holds 1 ½" dia. beaded or non-beaded vibrator. Vibrator Can grounded to chassis. Holding prongs designed to hold several types of Cans.





RUBBER FOOT

Snap-in Rubber Foot for Record Changers and Phonograph Mountings eliminates threaded member, lock washer and nut thereby speeding assembly time and reducing costs.

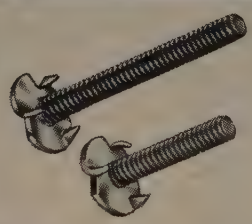


NYLON COIL NUT

Designed to snap into a TV tuner and receive a 4-40 or 4-48 coil adjusting screw. No coil form or coil form fastener required.

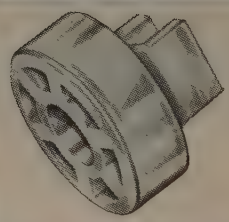
SPEAKER MOUNTING BOLT

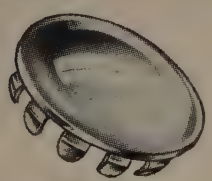
Pronged head prevents bolt from turning in speaker panel during application of nut and lock washer, permits one-side attachment providing production-line savings.



NYLON SNAP-IN NUT

Serves as insulator between "hot TV chassis" and cabinet. Snaps into square chassis hole and secures to cabinet with sheet metal screw.





PLUG BUTTONS

Made to snap into hole sizes ⅛" to 3". Can be embossed with ornamental or functional designs. Removable. Supplied with various finishes, in a variety of shapes and sizes.



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Eliminates need for welding or swaging studs to sheet metal stampings, facilitates nesting, eliminates damage in transit because Quickey snaps in just before final assembly.

TRIMOUNT STUDS

Designed to hold two or more thicknesses of material together. Easily installed by hand. Insure vibration proof attachment. Permanent or removable attachment. Wide variety of shapes and sizes.



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Parts illustrated are representative of the thousands of different specialized fasteners and allied devices designed and manufactured in volume by United-Carr and its subsidiaries for leading manufacturers of electronic equipment. United-Carr's wide and varied experience with special fastening problems in the automotive, aviation and appliance fields provides an unequaled background of technical knowledge which may well be applicable to your special needs.

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FASTENER CORP.

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BOOTHS 2533 to 2536 I.R.E. SHOW

Whom and What to See at the Radio Engineering Show

(Continued from page 406A)

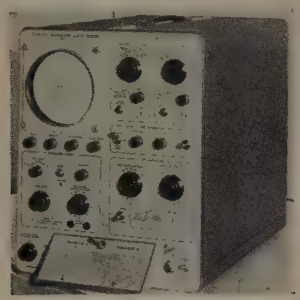
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- DC to 20,000 MC
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- Low frequency lumped circuit type components for microwave distributed circuits

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Transistor Servo Amplifiers, Rotor Balancers, Air Data Instruments, Inertial Navigators, Bombing Systems.

(Continued on page 410A)

In response to the trend toward Single Sideband



A new Signal Generator (Crosby Model 160A) designed to meet the requirements of single-sideband receiver tests and also provide low-distortion double-sideband modulation for testing high-performance systems.

. . . Provides continuous coverage from audio frequencies to 1.5 mc

. . . Choice of five crystal controlled frequencies, 1.5-30 mc

. . . Is versatile-generates:

- all forms of SSB including an ideal single-sideband signal, independent sideband modulation and inverted speech.
- all forms of DSB including low-distortion AM, carrier eliminated AM or quadrature modulation.

For further information send for Technical Publication No. 258A.

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From miniature components to integrated systems

AMF has electronics experience you can use

• AMF experience in electronics covers practically every area of the field, from design through production, of individual components and complete systems, for both government and industry.

• AMF has organized development and production teams experienced in the latest mechanical and electronic techniques. These teams, located throughout AMF, achieve the fine balance so necessary to produce efficient, reliable equipment.

• Particular AMF electronics capabilities and products include . . .

Data Processing and Display • Training Devices and Simulators • Antennas and Mounts
Communication Systems • Low-frequency Radar • Electronic Warfare Devices
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Guided Missile Support Equipment • Industrial Relays • Silver-zinc Batteries
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Research, Development, Production in these fields:
- *Armament*
- *Ballistics*
- *Radar Antennae*
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- *Auxiliary Power Supplies*
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QUALITY INSTRUMENTS FOR PRECISION TESTING OF *Tomorrow's Circuitry*

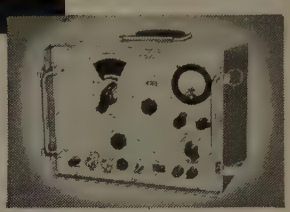
SG-25 STANDARD SIGNAL GENERATOR



Equivalent to AN/URM-25D. For alignment of radio receivers, measurements of receiver sensitivity and selectivity, and in all radio frequency voltage measurement work.

- Frequency Range: 10 KC to 50 MC in 8 bands
- Calibrated Output: 0.1 to 100,000 microvolts into 50 ohms
- High Output: 2.0 volts, 500 ohms impedance

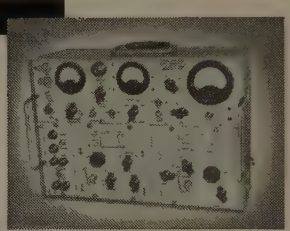
SG-26 STANDARD SIGNAL GENERATOR



Equivalent to AN/URM-26B. For alignment of radio receivers, measurements of receiver sensitivity and selectivity, and in all radio frequency voltage measurement work.

- Frequency Range: 4 to 405 MC in 6 bands
- Calibrated Output: 0.1 to 100,000 microvolts into 50 ohms
- Output Impedance: 50 ohms nominal

RT-500 RECEIVER-TRANSMITTER TESTER



Equivalent to AN/TRM-1. Laboratory-quality portable instrument, designed to measure performance on transmitting and receiving equipment.

- Frequency Range: 190 KC to 400 MC
- Signal Generator Output: 2.5 to 100,000 microvolts into 50 ohms
- Transmitter Tester Power Range: 3 to 100 watts
- Volt/Milliwatt Meter: multi-range meter measures AC, DC volts and milliwatts

PO-400 PULSE OSCILLOSCOPE



Equivalent to AN/USM-38. Precision portable oscilloscope for analyzing amplitude and time characteristics of complex electrical waveforms.

- Transient Response: 0.06 microseconds (rise time)
- Square Wave Response: less than 5% drop at 50 cycles
- Deflection Sensitivity: 0.1V RMS per inch
- Sweep: 1 to 100,000 microseconds per inch, triggered or recurrent

AT-120 R. F. STEP ATTENUATOR



Designed for use in output systems of signal generators, precision microvolters, IF strips of microwave receivers, etc.

- Frequency Range: 0 to 1000 MC
- Attenuation Range: up to 120 db in ten steps
- Output Impedance: 50 ohms standard, 75 ohms optional
- VSWR: 1.1 up to 500 MC, 1.2 up to 1000 MC

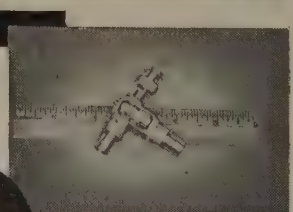
CS-200 SERIES COAXIAL SWITCHES



For all types of coaxial switching.

- Positions: up to 12
- Nominal Impedance: 5 ohms
- VSWR: 1.2 up to 500 MC, 1.3 up to 1000 MC
- Cross-talk for 12 Position: greater than 75 db down at 1000 MC

CM-300 CRYSTAL DETECTOR MOUNT



For general purpose in RF monitoring 50 or 75 ohm coaxial systems. Can be used with Trad Attenuator AT-120.

- Frequency Range: 10 to 1000 MC
- Accuracy: ½ db
- Impedance: available in 50, 75, 100, 150 and 225 ohms
- Maximum Signal Output: 2.5 V RMS

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Whom and What to See at the Radio Engineering Show

(Continued from page 408A)

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Hi-low temperature vibration chamber vacuum oven 1000° F; Tenney ten temperature cycling test chamber; Tenneymite 1½ cu. ft. extreme temp. cabinet.

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•10 MMF Miniature Teflon Coaxial Cable; Surface-Treated Teflon wire; Teflon Coated Magnet Wire KIT; MIL-W-7139A Airframe Wire; Teflon Insulated Wire and Cable to MIL-W-16878B and other Specifications.

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Tools, Dies, Instruments, Diamond Phonograph Styli.

Texas Instruments, Inc.
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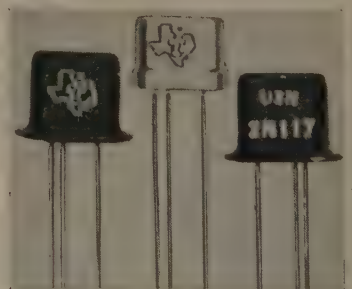
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Reflex and Navy Approved Transistors

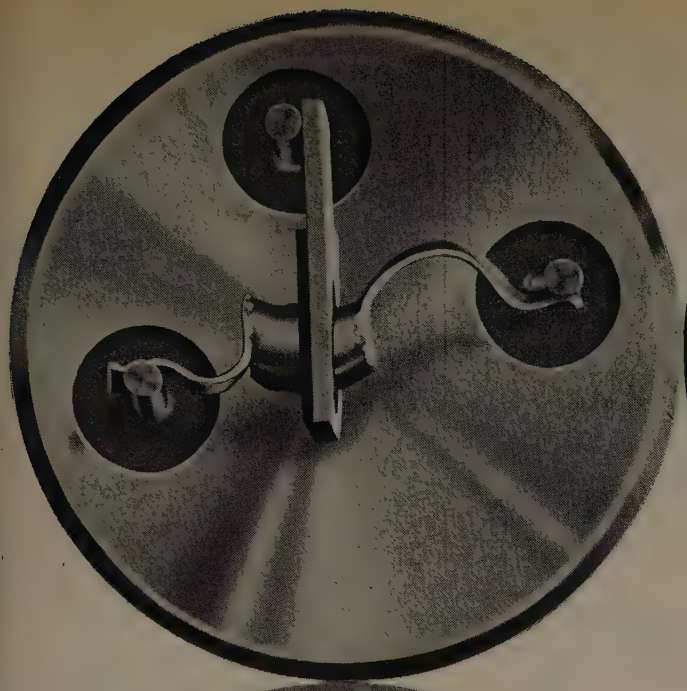
Germanium and silicon transistors, diodes, rectifiers. Precision resistors and panel meters. Recorders and industrial instrumentation. Transistorized military apparatus. Precision optical components.

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47 Bacon St.
Watertown, Mass.

Paul H. Forte, Paul Robey, Jr., Philip Barker, Robert Lindgren, A. S. Krimmer, O. O. Fautex, Murray Mathews

Textile's Nylon Monotape. A complete line of cotton, linen, Nylon, Dacron, Teflon lacing tapes and cords.

(Continued on page 412A)





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In computer or in other applications where current must be amplified in either direction, you can now specify General Transistor's new GT-34S bi-directional transistor.

As developed by GT, this symmetrical transistor can also be used as a bi-directional switch when placed in series with the load. For greater reliability, to save production time, and for compactness you should examine GT's-34S . . . another reason for General's leadership in the manufacture and development of transistors for computers.

Write for Bulletin GT-34S for complete specifications.

I.R.E. Booth 3828

GT's-34S magnified 10½ times.

Maximum collector to base voltage	40 volts
Maximum emitter to base voltage	40 volts
Peak current	½ amp.

DC current gain is > 10 when I_b = 20 ma, Vce ≦ .3 V.



GENERAL TRANSISTOR CORP. 91-27 138th Place, Jamaica 35, N. Y. OLympia 7-9700

Precision Welds

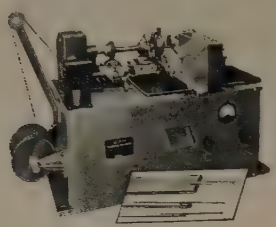


AUTOMATIC precision combined forming and welding operations that are accomplished on "TWEEZER-WELD" equipment have revolutionized the Electronic and Instrument industries.

Brochure Mailed on Request



Model TW—1 Low Inertia Welding Head (can be furnished with either capacitor discharge power supply or standard 1 KVA controls).



Automatic Welder
3600 welds per hour.



TWEEZER-WELD GUN

● Contract Welding Service Available

Millions of small parts have been made on TWEEZER WELDERS

TWEEZER-WELD

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FOR *Vibration analysis*

THE TP-625 FREQUENCY ANALYZER



FEATURES

- LINEAR FREQUENCY CALIBRATION
  Manual or Automatic Sweep
- EXCELLENT STABILITY
  Temperature Controlled bridge-stabilized oscillator
- CONSTANT FREQUENCY BANDWIDTH
  As narrow as 2 cps; as broad as 200 cps
- DYNAMIC RANGE
  As great as 66 db (depending upon filter employed)
- SPECTRUM
  2 cps to 25,000 cps
- MULTICHANNEL ANALYSIS
  Simultaneous analysis of numerous channels

The TP-625 Frequency Analyzer will determine the recorded frequency-amplitude spectrum of a random wave within the frequency range of 2 cps to 25,000 cps. In addition to analyzing random waves, the instrument will also determine the frequency and amplitude of the individual components in a periodic wave within this frequency range

Wave components resulting from vibration, pressure, strain, light, etc., can be measured in decibels, in percent of total signal or both. Results are indicated on a calibrated attenuator and on a meter. For permanent, detailed analysis, high and low impedance output are provided to drive a recorder When equipped with its accessory servo system, the TP-625 will follow RPM, or multiples of RPM, in engines throughout an operating range

For specifications and further information, write for bulletin 625-1-956.

Technical Products Co.
INSTRUMENT DIVISION
6670 Lexington Ave. Los Angeles 38, Calif.

Whom and What to See at the Radio Engineering Show

(Continued from page 410A)

Thomas Electronics, Inc., Booth 2233
118 Ninth St.
Passaic, N. J.

John Ouse, Ivan J. Posner, ▲ Henry Schmalz, ▲ Bernard L. Loring, ▲ Nick Broderick, ▲ John B. Loschiavo

*Wide Angle 110° Picture Tubes—Shorter—Lighter—Ion Trapless. Original equipment and replacement type cathode ray tubes. Electron Gun Mount Assemblies.

Thomas Instrument Co., Booth 4128
See: R & S Electronic Sales

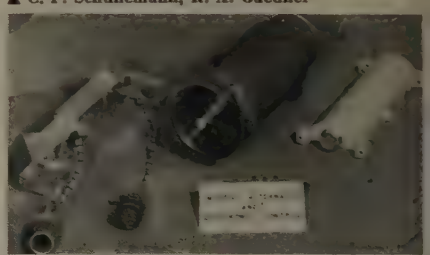
Thomas & Skinner, Inc., Booth 2926
1120 East 23rd St.
Indianapolis 7, Ind.

J. C. Skinner, S. J. Garvin, C. T. Thomas, A. W. Reed, W. M. Kurman

SiFeMag Tapes 0.001 to 0.007" thick, now available in slit widths; Orthosil standard and three phase laminations, Orthosil wound cores; and Alnico 5Cb permanent magnets.

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Booths 2527-2531

F. J. Weihmiller, O. D. Page, R. T. Myers, B. C. Keach, D. A. Schonmeyer, R. I. Armstrong, ▲ C. F. Schunemann, R. A. Gaedner



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Thor Ceramics, Inc.
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Bloomfield, N. J.
Booth 4216

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New York 19, N. Y.
Booth 1824

M. B. Helme

Data recorders, timing devices. Facsimile communications equipment.

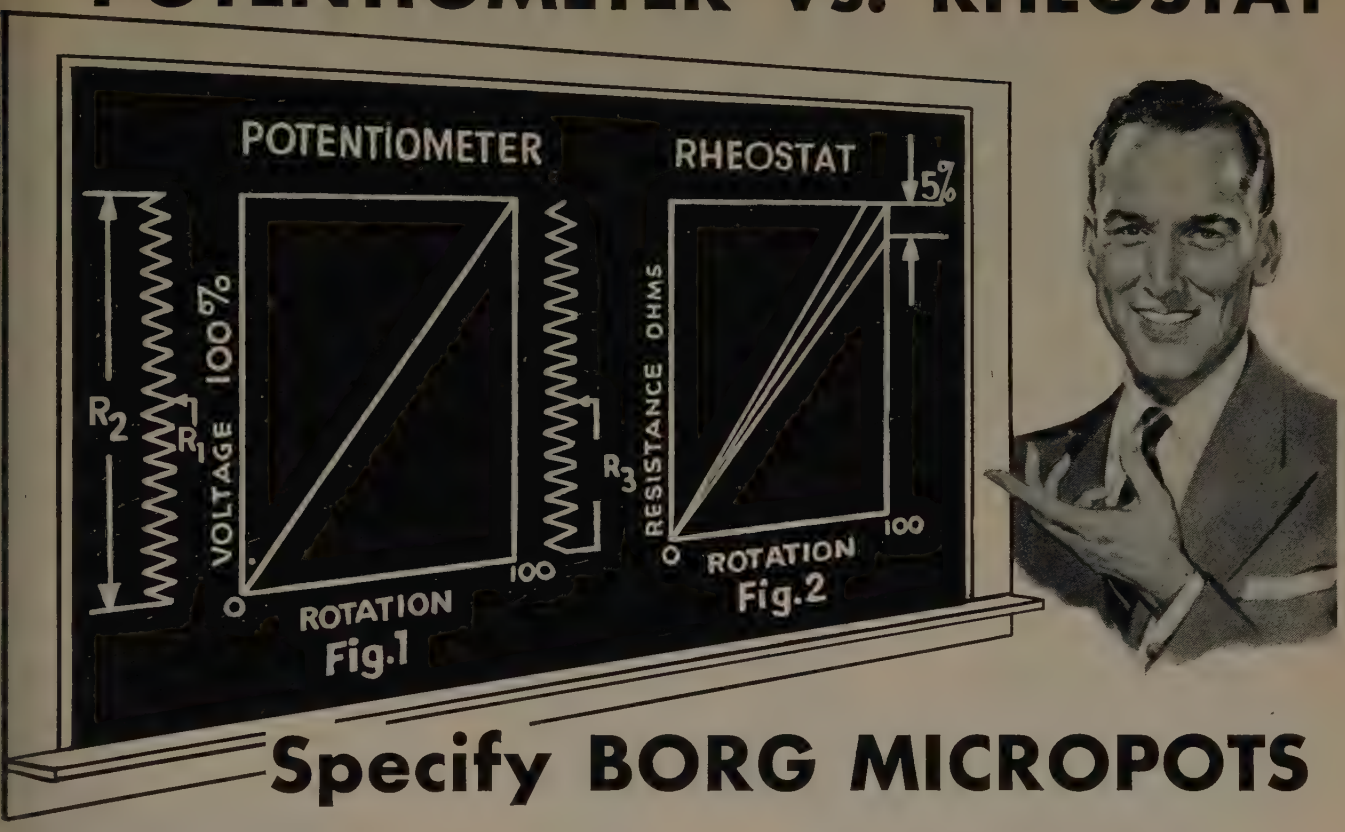
Tinnerman Products, Inc., Booths 4207-4209
P.O. Box 6688
Cleveland 1, Ohio

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Featuring comprehensive display of cost saving spring steel SPEED NUT brand fasteners for electronics industry. Complete line of tube, harness clamps; wire and cable clips. Introducing new "Pinch Grip" fasteners.

(Continued on page 414A)

POTENTIOMETER Vs. RHEOSTAT



Specify BORG MICROPOTS

Potentiometer Vs. Rheostat. Potentiometers should be used whenever possible to reduce systems error and excessive cost. Here's why.

POTENTIOMETER as a POTENTIOMETER

Definition: A potentiometer is a voltage divider.

Accuracy — Potentiometer accuracy is determined by the ratio of R_1 to R_2 for any given position of the control shaft (Fig. 1). Potentiometer accuracy is *independent* of total resistance. Commercial precision potentiometers are designed for use as voltage dividers. Therefore, the total resistance is $\pm$ 5%. However, the output voltage is the ratio of R_1 to R_2 and provides a linearity accuracy of 0.1% (Fig. 1). Linearity accuracy in commercial precision potentiometers is 0.1%.

POTENTIOMETER as a RHEOSTAT

Definition: A rheostat is a variable current control.

Accuracy — When used as a rheostat (2 wire hook-up) the accuracy of the potentiometer is determined by the absolute resistance R_3 for any given position of the control shaft (Fig. 2).

Rheostat accuracy is *dependent* upon the absolute resistance at any point.

Commercial precision potentiometers, when used as rheostats, have an absolute ohmic resistance R_3. It may deviate from zero to 5% from theoretical over the range of zero to 100% of shaft rotation (Fig. 2). Errors in distribution of this resistance (comparable to potentiometer linearity tolerance) must be added to this error to ascertain the "total ohms per degree conformity", the true measure of rheostat accuracy.

Consider the possibility of a closer total resistance tolerance to provide greater accuracy when used as rheostats. Commercial tolerance on fixed resistance is 5% with special selected values to 1%. This selected accuracy, if duplicated in a rheostat, would still be 10 times greater than the standard 0.1% accuracy of the commercial potentiometer. Factors which contribute to the difficulty in tight total resistance tolerances in fixed resistors are: resistance stability, temperature coefficient, and the absolute ohmic value of commercially available resistance alloys.

These limiting factors apply to potentiometers used as rheostats. This increases the cost of such units just as the cost of tight tolerance fixed resistors is considerably greater than standard tolerances.

We have found, through years of building potentiometers, designing equipment and in consultation with customers, that when systems can be designed to use potentiometers in place of rheostats, greatly increased accuracy results and usually the cost is reduced.

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BORG EQUIPMENT DIVISION
THE GEORGE W. BORG CORPORATION
JANESVILLE, WISCONSIN

ELECTRONIC – MECHANICAL BORG EQUIPMENT

Built by Borg

Whom and What to See at the Radio Engineering Show

(Continued from page 412A)

Tower Construction Co., Booth 1223
2700 Hawkeye Drive
Sioux City, Iowa
C. A. Wright
Microwave towers, reflectors.

Transitron Electronic Corp.
403-407 Main Street
Melrose 76, Mass.
Booths 3912, 3914

▲ D. Bakalar, ▲ J. Hangstefer, ▲N. De Wolf, ▲ W. Slusher, L. Dixon

Silicon voltage regulators are featured in complete line of silicon devices including fast switching—high conductance—high voltage silicon diodes, military type silicon rectifiers and diodes.

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Wideband sweep generator—ultraprecise HF & VHF alignment instrumentation HF, VHR & VHF precision signal generators & laboratory accessories, H. V. insulation tester; communications transmitter & transreceiver.

Travco Associates, Booths 1230 & 1232
148-03 Hillside Ave.
Jamaica 35, N. Y.
Ted Greenburg, J. Duncan, S. Krasnow, ▲ E. V. Naybor, J. Traise

Warren Mfg., Magamp for polarized relays, Airborne Inc., missile motors, generators. Magtrol, magnetic clutches, servomotor dynamometer; Gorator Corp., 400 cycle generators; North American Ins., miniature tape recorder, transducers.

Triad Transformer Corp.
4055 Redwood Ave.
Venice, Calif.
Booth 2244

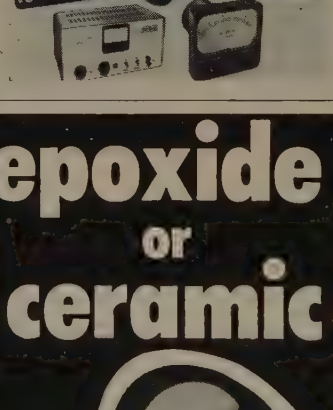
▲ L. W. Howard, Ernest Clover, Ralph Weiler, Arnold Kaufman

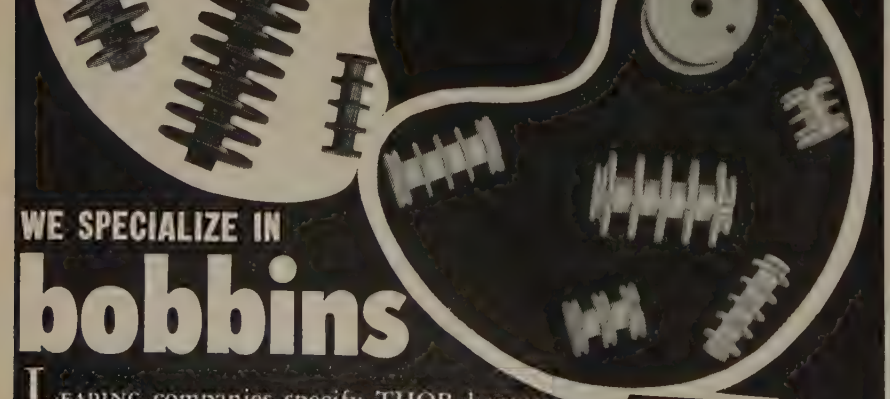
*Line of pulse transformers.

*Line of transistor transformers for all applications.

Trio Laboratories Inc.
4025 Merrick Rd. Seaford, L. I., N. Y.
Booth 3020

▲ Jay S. Salz, Dr. Robert E. Corby, Jerry Worthing, J. Grannaik, J. Van Putten





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Tru-Connector Corp., Booth 3949
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RF coaxial connectors.

Tru-Ohm Products Div.
Model Engineering & Mfg., Inc.
2800 N. Milwaukee Ave.
Chicago 18, Ill.
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95 Eighth Avenue
Newark 4, N. J.
Booths 2813, 2815

John D. Van der Veer, John M. Malone, Bruce Blakeslee, Fred Warren, L. E. Schaefer, ▲ Morris Levine, ▲ Gene Peet, ▲ Rod Bell, ▲ Alex Mitchell, ▲ Robert Jarmick, ▲ James Kuykendall, ▲ C. W. Duncan, ▲ J. W. Sheriff, ▲ B. Carlat, ▲ L. L. Emmel, ▲ H. S. Evander, ▲ M. Hower, ▲ E. Sussman

*12AL8 triode space charge tetrode to be shown with demonstration of manufacturing operations from electron tube and semiconductor plants.

Turbo Jet Products Co., Inc., Booth 3924
424 South San Gabriel
San Gabriel, Calif.
Otto N. Bloom, Richard L. Bloom
Coils "HI-TEMP Sub Miniature Non Gassing"

(Continued on page 416A)

* Indicates new product
▲ Indicates IRE member

"Whom and What to See at the Radio Engineering Show" will be reprinted in a digest-sized booklet to be distributed to every registrant at the Show and Convention.

NOW... the world's most Versatile Coil Winder available as a complete laboratory unit!

MODEL W COIL WINDER

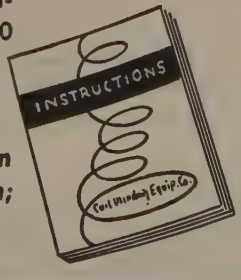
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SPECIFICATIONS

⅛ HP motor and speed control—Gears from 25-100 teeth—Wire Guide for universal or lattice winding—Wire Guide for bobbins or layer winding—Wire Guide for single or multiple layer coils to 6" in length—3:1 reverse idler for bank winding and long multiple layer coils—Cams for continuous traverse adjustment, 0"-1½"—Large yoke for larger bobbins and transformers—Available with clock counter calibrated in ¼ turns or with drum type predetermining counter—Universal type arbor for coils with hollow cores—Pi spacing attachment with 1/32 index plate—Adjustable bank winding cam—Feeds for wire as fine as .001"—Rack feed range .00083" to .150" per turn (7-1200 TPI). Maximum distance from head to tailstock 8"—Layer wound coils using cam traverse 2 to 600 TPL. Net weight 140 lbs.



Model W with cabinet comes with 50 page instruction book complete with charts for universal computation; work sheets and nomographs.

Cabinet made of auto body steel with reinforced corners and ends; heavy duty ball bearing rubber tired caster with 2 foot brakes; size 17x25½x32" high; one cylinder lock secures all compartments.



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Model CU-2T control unit is designed to stabilize and track any two electronically regulated DC power supplies to .01% for operational amplifier service. Error signals from both sources are referenced to a zener junction diode network in a temperature stabilized oven. Output correcting voltages are automatically clamped to any DC level.

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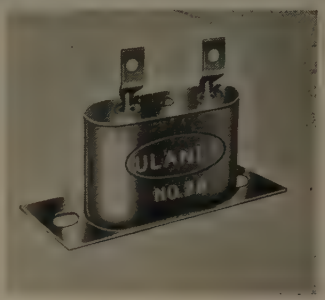
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specifying output voltages and currents or visit
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AT THE IRE SHOW.

Whom and What to See at the Radio Engineering Show

(Continued from page 414A)

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E. Lafean, H. Myers, F. Hesch, W. Dunn, J. Hansen, K. Doriot



Alpha Numerical Data Display Indicators

*Union Digital Indicators with companion product alpha-numerical Data Display Indicators. Also featuring our reliable AC & DC Miniature Relays with Gold Alloy Contacts.

(Continued on page 418A)

Solve core problems quickly, economically with

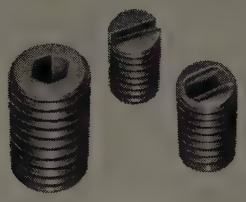
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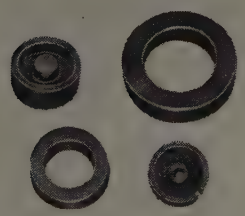
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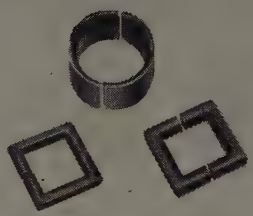
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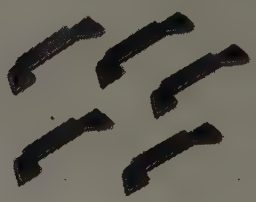
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$$C/R=\frac{(K_1K_2K_3)(1+j\omega T_1)(1+j\omega T_3)}{j\omega(1+j\omega T_2)[(1+j\omega T_3)(1+j\omega T_-)+(K_6K_7K_8K_9)]+(K_1K_2K_3)(1+j\omega T_3)(1+j\omega T_3)}$$

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In addition to functioning as a complete system simulating laboratory, the Servomation Building Blocks offer accurate, rapid debugging of existing systems or components. Self-contained and mobile, the Building Blocks can analyze complete industrial, aircraft and missile systems on the spot, without the need for multiple test units with varying accuracies.

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The Servomation Building Blocks will be at the IRE SHOW
See it at BOOTHS 3615-3617

Whom and What to See at the Radio Engineering Show

(Continued from page 416A)

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Edward Nickel, Edward Silisbury, Tony Andrew

The world's most flexible metal framing. 100% adjustable—100% reusable—no welding—no drilling—no special tools needed.

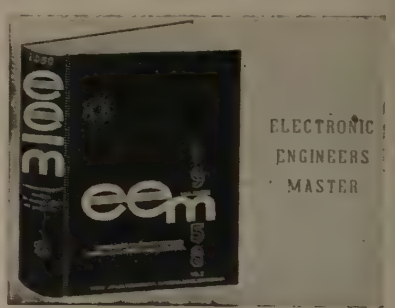
United-Carr Fastener Corp.
The Ucinite Company Div.
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Booth 2536

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Terminals, Lamp shields and sockets, spacer sleeves. Dial Light assemblies—appliance lighting and snap switches—Anode connectors—test jacks—vibration isolators.

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New York 13, N. Y.
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A. E. Stevens, Arthur I. Rabb, Samuel Roth, George M. Kerner, George Siegel, Robert J. Males



Electronic Engineers Master—Components, Equipment, Services for Research and Production; 1957 Radio-Electronic MASTER, Official Buying Guide; FILE-O-MATIC, Perpetual electronic catalog service; PRICING SERVICE, Industry-wide electronic parts and equipment pricing book.

United Mineral & Chemical Corp.
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New York 13, N. Y.
Booths 1321, 1323

Irwin Stelzer

Ceramics & deposited carbon resistors, transistor & tube components & raw-materials, mica material & fabricated military material, aluminum foils.

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140 Federal Street
Boston, Massachusetts

R. W. Daniels, P. E. McGinness, G. C. Mayo, Newton Macleod, R. P. Marchand

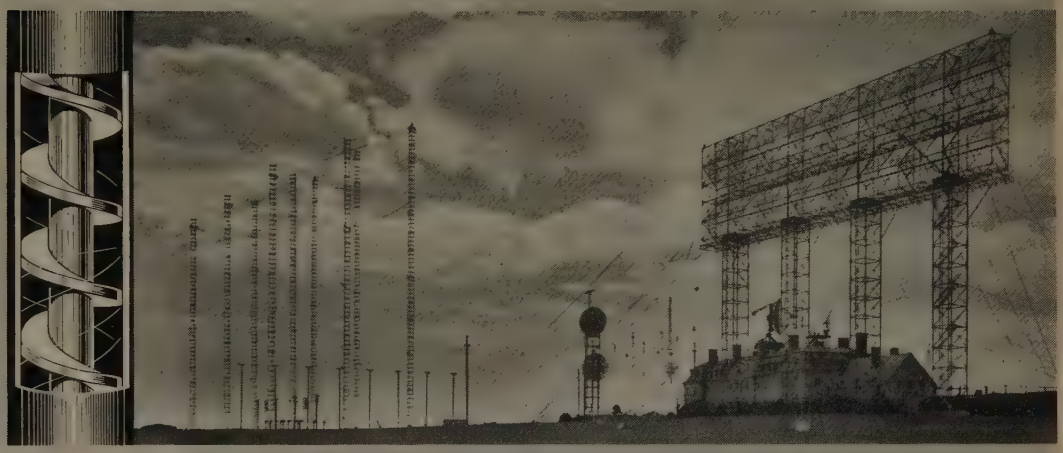
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U. S. Ceramic Tile Co., Booth 4217

See Diamonite Products Div. and Sparta Mfg. Co. Div.

(Continued on page 420A)

Demonstrating Outstanding Characteristics
for Forward Scatter Systems...



Round Hill Field Station, M.I.T.'s Lincoln Laboratories, South Dartmouth, Mass.

Styroflex Coaxial Cable

A recent series of experimental tests conducted by the Round Hill Field Station of M.I.T.'s Lincoln Laboratories at South Dartmouth, Mass., clearly showed that Styroflex coaxial cable has a number of practical advantages when used as the connecting link between the antenna and transmitter or receiver in forward scatter systems.

The tests demonstrated the particular importance of these general Styroflex characteristics:

1. 1000-foot continuous lengths without splices.
2. Low attenuation.
3. Excellent electrical properties.
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Inquiries regarding specific applications for Styroflex are invited.

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Output: 250 VDC @ 200 MA
Regulation: ±1% against load variations from ¼ to full load, and over entire input voltage range.
Size: 2¾" x 2¾" x 3¾"
Weight: Approx. 2 lbs.

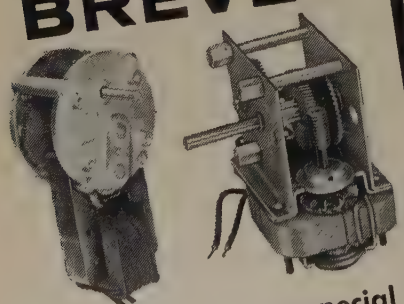
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BOOTH 3940 & 3942 NEW YORK IRE SHOW MARCH 18-21

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Dept. IRE 37 EDgewood 3-3304

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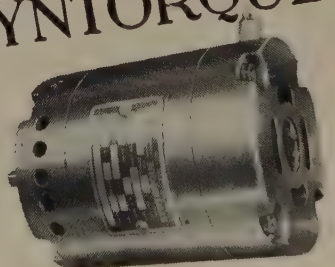
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Whom and What to See at the Radio Engineering Show

(Continued from page 418A)

U. S. Components, Inc.
454-462 East 148th St.
New York 55, New York
Booth 2706

A. Jackson, ▲B. A. Jackson, S. Nalbantian, H. Nalbantian, M. Berger

FBI—Floating body isolation double lead screw lock connectors. Miniature—sub-miniature—power multi-contact connectors—printed card connectors, receptacles.

United States Dynamics Corp., Booth 3053
1250 Columbus Avenue
Boston 20, Mass.

▲E. J. Cagney, ▲D. Drew, ▲C. E. Holmes, ▲S. A. Shaw, S. Tetelbaum, ▲Dr. W. E. Strimling

Development sample diodes for operation at 375°C ambient and storage at 400°C. Complete line of Silicon diodes and rectifiers for operation at 275°C ambient.

U. S. Electronics Development Corp.
1323 Airway
Glendale 1, Calif.
Booth 3934

H. B. Rothbard, Edward C. Raymund

Standard cataloged Polystyrene, Mylar and Teflon capacitors. High quality metallized paper, metallized Mylar and paper capacitors.

U. S. Engineering Co., Booths 3814, 3816
521 Commercial St.
Glendale 3, Calif.

William Simonite

Printed circuits, terminal lugs, hardware, terminal board.

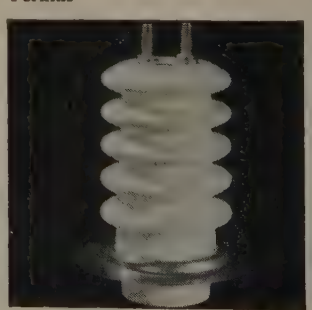
United States Gasket Co., Fluorocarbon Prods., Inc., Div., Booth 4036
932 Kaighns Ave.
Camden, N. J.

Charles C. Colozzi, A. J. McMullen, H. S. Stott, R. A. Graeff

100% Teflon Copper Clad Printed Circuit Material. Teflon Test Points and Components in full RETMA Colors.

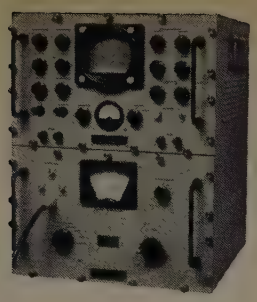
U. S. Stoneware Co.
Alite Division
Orrville, Ohio
Booth 4236

J. M. W. Chamberlain, Herman Frahme, W. E. Coykendall, Jr., Howard Farkas, Ralph Gross, Walter Perkins



Mass spectrometer tested ceramic-to-metal seals. High temperature vacuum-tight. Also new line of standard high voltage terminals, 2 and 2¾" diameters, 2 to 8 flutes, optional single, double or triple terminals.

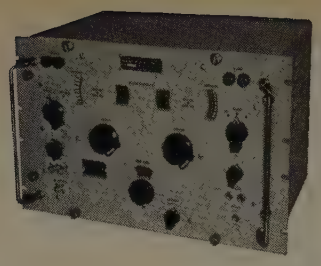
(Continued on page 422A)



LA-18 SPECTRUM ANALYZER

Bench-size Spectrum Analyzer featuring high stability and wide range in small size.

Continuous coverage, 10.0 to 16,000 mc calibrated without external heads. 3.0—32,000 mc usable range. 0.5 to 25 mc spectrum width, 7.5 kc resolution. Internal spectrum calibrator. Bulletin LA-18



LA-61 FREQUENCY METER

Highly accurate UHF Frequency Meter featuring internal calibration, rugged construction.

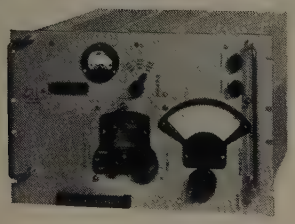
Frequency range 500 to 2000 mc in two bands, 0.001% accuracy, precision high-speed semi-direct calibration, 0.0001% oven-controlled crystal standard. Standard 19" panel 12¼" high, rack or table mounting. Bulletin LA-61



LA-593 PULSE GENERATOR

Light, compact, double-pulse generator for general field or laboratory use. Bench or rack mounting.

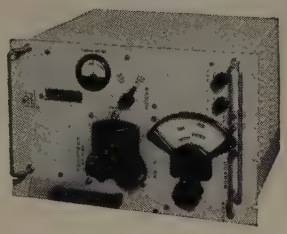
20-200,000 pps internal trigger, 0-200 kc external; 1.5 to 2500 microsecond delay, 0.5 to 2500 microsecond pulse width, one or two pulses. Output impedances 2000, 200 or 75 ohms. Approx. 0.1 microsecond rise time. Bulletin LA-593-D.



LA-5 FREQUENCY METER

Convenient field instrument designed and built to military standards for fast and accurate frequency measurement.

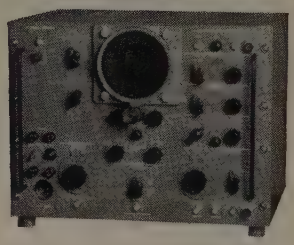
Frequency range 10 to 100 mc in three ranges, color-coded scales for use by production line personnel, semi-direct calibration, accuracy 0.001%, internal oven-controlled crystal standard, 0.0001%, input less than 500 microvolts. Standard 19" panel, 12¼" high, rack or table mounting. Bulletin LA-5-6.



LA-6 FREQUENCY METER

VHF frequency meter matching LA-5 in appearance, identical in operation.

Frequency range 100 to 500 mc in two color-coded ranges. Internal high-speed semi-direct calibration, with accuracy of 0.001%, internal oven-controlled crystal standard 0.0001%. Input less than 500 microvolts. Standard 19" panel, 12¼" high, rack or table mounting. Bulletin LA-5-6.



LA-239C OSCILLOSCOPE

General purpose, wide band oscilloscope, covering 5 to 20 mc, military standard construction, nomenclature AN/USM-50.

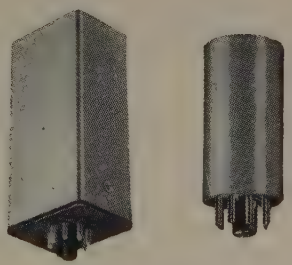
Frequency range 5 cycles to 15 mc flat, 0.03 v/cm sensitivity, internal voltage calibration, Z axis timing markers 0.2 to 2000 microseconds, internal trigger generator. Sweep speeds to 14 cm per microsecond. Ruggedized construction, standard rack mount. Bulletin LA-239C.

NEW!

LA-259 OSCILLOSCOPE

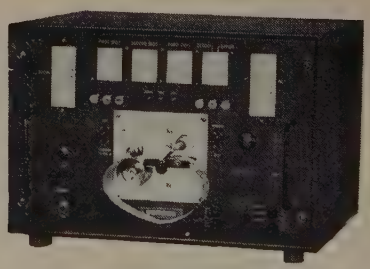
Five-inch militarized high-performance oscilloscope incorporating all the features of the famous LA-239C *PLUS:*

- **5 inch flat-face screen**
- **DC to 15 mc response**
- **Verified dual-accuracy calibration**
- **Simplified read-out**



CRYSTAL OVENS

Standard and miniatures, to ± 0.025°C, in more than 20 catalog types. MIL-T-945A Specs for airborne or other severe use. Over 30,000 in use. Write for special catalog.



ROBOTESTER

Automatic tape-controlled equipment tester checks 1 ohm to 10 megohms from any of 240 points to any other. Change over in seconds; sets up in as little as an hour. Up to 100 tests per minute.

Representatives in Albany, Atlanta, Baltimore, Chicago, Denver, Euclid, O., Fort Worth, Hartford, Los Angeles, Montclair, N.J., San Carlos, St. Louis, Ottawa

Lavoie Laboratories, Inc.

MORGANVILLE, NEW JERSEY

DESIGNERS AND MANUFACTURERS OF ELECTRONIC EQUIPMENT



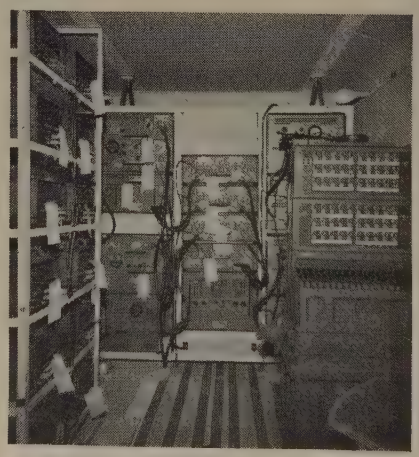
This self-contained radio relay station can be operative within minutes of landing. It carries its own antennas and has its own lighting and ventilation systems.

THE NEW CRAIG HELICOP-HUT*....
"flying" shelter that operates anywhere!

This is the Helicop-Hut, designed and built by Craig . . . a lightweight portable shelter for electronic equipment that can operate anywhere a helicopter can reach.

FEATURES:

- Light weight — 950 pounds
- Payloads — over 6000 pounds
- Insulation factor — 0.24
- Aluminum skin bonded to foamed-in-place core for maximum strength, minimum weight
- Inside dimensions — 76″ x 76″ x 96″ long
- Meets Government specifications for world-wide use
- Special Accessories: lifting device for truck loading; quickly-attachable dolly to make Helicop-Hut mobile



Interior of Helicop-Hut TCC-11 Communications Central showing transmitters, telephone switchboard and communications equipment.

USES:

AGC landing systems, missile and aircraft test checkouts, missile flight control stations, communication and navigation systems, and maintenance workshops.

For full information, write Craig today.

* Trademark

Craig SYSTEMS, INC.

Dept. P-3 Danvers, Mass. Tel.: SPring 4-1870

OTHER CRAIG PRODUCTS: *transportable and mobile electronic systems, shelters, trailers, vans, mobile control towers, missile carriers, re-usable shipping containers, antennas and masts.*

SEE THE HELICOP-HUT ON DISPLAY AT THE IRE SHOW, BOOTH 1325, MARCH 18-21.

Whom and What to See at the Radio Engineering Show

(Continued from page 420A)

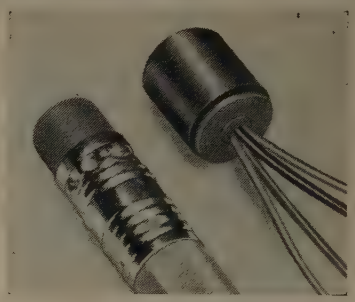
The United States Time Corp., Booth 2335
500 Fifth Avenue
New York 36, New York

▲ G. W. Boehm

Sub-miniature precision rate gyroscopes—World's smallest, lightest, most rugged. Fast starting, excellent resolution and linearity. Unusually insensitive to shock and vibration.

United Transformer Co.
150 Varick St.
New York 13, N. Y.
Booths 2413, 2414

H. Russell, T. L. Craige, J. Barresa, Walt Rooney, Bob Soveyn, Aussen Profeta



Transistor Transformer

DOTs—A revolutionary transistor transformer line which fully meets MIL-T-27A specifications. Complete line of military, industrial, "Ham," broadcast and replacement transformers. Filters, toroids, mag amps, pulse.

Unitek Corporation
Weldmatic Division
380 No. Halstead Ave.
Pasadena, Calif.
Booths 4517-4519

Gerald E. Woods, William Rounsful, Morrie Cowgill, Frank Page



Precision Welding Supply

Printed circuit welding with *Weldmatic technique and equipment. Also see *Heavy duty, bench mountable welding head and power supply.

(Continued on page 424A)

* Indicates new product
▲ Indicates IRE member

MORE DATA

Exhibitors shown in boxed listings, or using illustrations of new products, have provided more data for you in their show preview advertisements in the advertising pages of this issue. See Index to Advertisers, beginning on page 449A.

LARGE WAVEGUIDE



Slotted line for waveguide size WR 2100. Covers range of 350-530 mc. Probes tunable over entire band. Inherent VSWR less than 1.02—slope less than 1.01. Features bolted and doweled aluminum construction.

LARGE
WAVEGUIDE & COMPONENTS
WR 770 to WR 2300 (1450 down to 320 mc)

To complement the waveguide presently being supplied for major military and commercial applications in radar and scatter communications systems, we now offer a complete line of components and test equipment.

Terminations. Aluminum construction. Engineered to absorb virtually all incident power. Load is adjustable with locking device to secure it in any position.

Attenuators. Vane type designed to provide 20 db of attenuation with a minimum of mismatch. Calibration curves available.

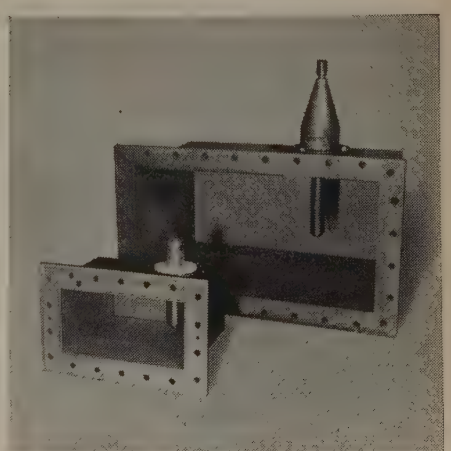
Directional couplers. Bolted and doweled aluminum construction. Power split to customer requirements.

Special components. Including waveguide switches, duplexers, diplexers, series and shunt tees, rotary joints, and special shapes.

All items are in production now and are available on short term delivery. For more information, write I-T-E Circuit Breaker Company, Dept. 45, Special Products Division, 601 East Erie Ave., Philadelphia 34, Pa.

VISIT THE I.R.E. SHOW, March 18-21
See this equipment displayed at Booth 1313-1315

I-T-E CIRCUIT BREAKER COMPANY
Special Products Division



Waveguide to coaxial transitions. High-strength, lightweight aluminum construction. Supplied as standard with 3⅛ in. coaxial connector (for WR 770 size, 1⅝ in.). Adapters to other sizes available. All transitions designed for high power handling capacity.

BOOTHS 2428-2521 IRE SHOW

Metallurgists and Specialists in SMALL WIRE for 56 Years

PRECIOUS METAL WIRES

Produced in Platinum, Gold, alloys and pure metals—small diameter . . . Platinum alloy resistance wires...Pure Iridium and Rhodium-Iridium alloy Thermo-couple Wire.

BASE METAL WIRES
Very small diameter — for filaments, thermo-couples, resistance units.

Since 1901

COATED WIRES

Comprising an extensive range of electroplated grid wires . . . Enamel insulated wires for precision resistors and potentiometers.



Write for List of Products

SIGMUND COHN CORP. 121 So. Columbus Avenue • Mount Vernon, N.Y.

Now, Component Leads Prepared Automatically

New Machines Reduce Hand Work, Speed Production

LONG OR SHORT RUNS

LEAD FORMER Cuts and forms coaxial leads to any desired shape and length. Over 5,000 parts per hour. Various feed attachments.

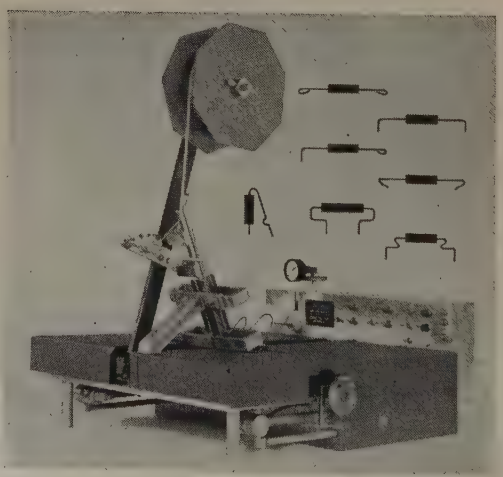
LEAD BENDER Bends leads to right angles and trims them to any length, equal or unequal. Up to 14,000 parts per hour.

LEAD STRAIGHTENER Automatically straightens and aligns pigtail leads. Up to 3,000 parts per hour. Easily coupled to other automation equipment.

LEAD TAPER Tapes on body, lead or both. Can be combined with other machines.

INSERT MACHINE Automatically locates and drills board holes—correctly inserts up to 24 different components.

Write for Catalog



LEAD FORMER with tape stripper attachment

On Display At IRE Show
Booth 4125 • New York Coliseum
MARCH 18-21

DESIGN TOOL CORPORATION

ELECTRO-MACHINERY DIVISION

78 Washington Street

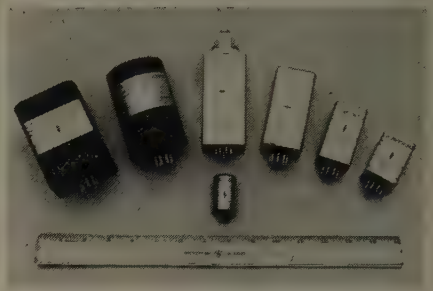
New York 6, N.Y.

Whom and What to See at the Radio Engineering Show

(Continued from page 422A)

Universal Atomics Corp.
19 East 48th Street
New York 17, N. Y.
Booths 3940 & 3942

James A. Gannon, Jr., Peter Paul Luce, ▲ Alfred Bender, ▲ Alan Pearlman, Maurice L. Goodman, Seymour Katz, Richard Silverman, ▲ M. Clifford Agress



Power Supplies from 1600V to 50 Watts

Compact lightweight all-electronic power supplies that eliminate size, weight, vibration and shock problems in airborne, military, commercial applications. Portable precision electronic and nucleonic instruments.

Universal Electronics Co., Booth 3950
1720 22nd Street
Santa Monica, Calif.

Power Supplies: HV Types; Electronically regulated DC types; Magamp types.

Universal Mfg. Co., Inc.
410 Hillside Ave.
Hillside, N. J.
Booth 4608

Gerhard Whitting, Richard Hillebrand, Bohdan Robak



Portable "Portoroid" Taper

Portable "Portoroid" taper for toroidal coils developed and perfected to fill an urgent need for simplified automatic precision winding of all types of commercial insulating tapes, except adhesive-backed tapes.

Universal Winding Company, Booths 4310-4311
1655 Elmwood Avenue
Cranston, R. I.

W. T. Crocker, A. W. Wachta, M. E. Fagan, C. J. Zaikowski, W. L. Rainford, H. W. Bowin, W. J. Quinn

*No. 111 machine for cross-wound coils. Automatic slow-start and other revolutionary features insure accurate coils at high speeds without adhesive agent.

V & M Tool Manufacturing Corp., Booth 4029
52 St. Casimir Avenue
Yonkers, N. Y.

L. J. Valle, C. J. Seibert, W. Palan, W. Jaris, M. Nichols, J. Grond

Color TV Cable Assemblies. Anode, Battery, Tuner, Phono, Yoke and Kinescope Connectors, Special Cable Assemblies.

(Continued on page 426A)

NATIONAL SYMPOSIUM ON TELEMETERING AND EXHIBITS

PHILADELPHIA

APRIL 14, 15, 16, 1957



L. P. CLARK

L. P. CLARK, *Convention Chairman*

Since 1934, Clark has served with Tele Dynamics, Inc. (Formerly Raymond Rosen & Co.) At present he is Executive Vice President of this Telemetering manufacturing and engineering firm, and has seen it grow under his supervision from 5 to over 700 employees. In 1935 Clark designed and directed first automatic radio-relay system using 30 megacycle frequency for the commonwealth of Pennsylvania, Dept. of Flood Control. In 1949 he directed the engineering and design of a complete radio-relay system for the Pennsylvania Turnpike.

Other achievements include establishment of systems for the Pennsylvania and New Jersey Turnpikes.



ARTHUR S. WESTNEAT, JR.

ARTHUR S. WESTNEAT, JR., *Papers Chairman*

Since 1949 he has been with the Applied Science Corporation of Princeton. Currently he is Assistant to Vice President of Engineering. His previous assignment was Chief Engineer for three years, 1952 to 1955. In 1946 Westneat was in charge of Systems Analysis Group, Electronics Division of Glenn L. Martin Co. in Baltimore.

Currently he is Vice-Chairman of the Philadelphia Section of the IRE-professional Group on Telemetering and Remote Control, and is Papers Chairman for the National Symposium on Telemetering.

Philadelphia's new Sheraton Hotel is the home of the 1957 International Symposium on Telemetering. Just opened on March 6, 1957, it is a real showplace. Completely air conditioned, it was carefully planned to provide complete convention facilities. Comfortable wall-of-glass rooms equipped with radio and television, excellent meeting rooms for Technical Sessions and exhibits. Fine restaurants for a quick snack or a full course dinner. Modern garage and close to public transportation. Center city location assures you convenient and comfortable stay.



SPONSORED BY THE PROFESSIONAL GROUP ON TELEMETERING AND REMOTE CONTROL

32 papers on important and significant aspects of this group will be presented at this great meeting on the following subjects:

Remote Control, systems and applications. Remote Control, theory and applications. System Elements for telemetering and remote control.

●

EXHIBITS

65 fine exhibits on new and important products you will not want to miss.

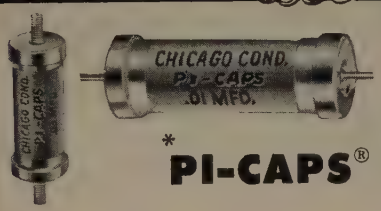
●

REGISTRATION

Advance registration information can be procured from Mr. Henry W. Royce, THE GLENN L. MARTIN CO., BALTIMORE 3, MARYLAND.

What's New in Caps *



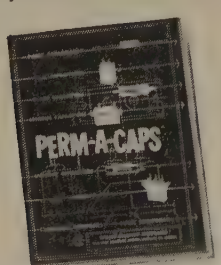


* **PI-CAPS®**

FROM 10 VDC TO 100,000 VDC
SPECIALIZING IN 1% TOLERANCES

Highly desirable for critical applications in limited space. Heavy wall pyrex with metal end caps. Designed for computers and control equipment, they have high insulation resistance and stability vs. temperature, low dielectric absorption and power factor.

Call on us for all your film capacitor requirements. POLYETHYLENE, ACETATE, POLYSTYRENE, and MYLAR capacitors.



Write Dept. A

CHICAGO CONDENSER CORPORATION

3255 WEST ARMITAGE AVENUE
CHICAGO 47, ILLINOIS

KING-MOON COMPANY
15044 VENTURA BLVD.
SHERMAN OAKS, CALIF.

M. CLIFFORD AGRESS
891 FULTON STREET
VALLEY STREAM, N. Y.

Z. S. MEYERS, 4538 MAIN ST., KANSAS CITY 11, MO.

Whom and What to See at the Radio Engineering Show

(Continued from page 424A)

Vacuum-Electronic Engineering Co., Booth 4208
86 Denton Ave.
New Hyde Park, L. I., N. Y.
Albert Nerken
Pumps, leak detectors, vacuum valves, gauges.

Varian Associates
611 Hansen Way
Palo Alto, Calif.
Booths 2530, 2532, 3514

Dr. Emery Rogers, Dan Lansdon, Gene Watson

Varian's new G-11 Strip Chart Potentiometer Graphic Recorders, for rack mounting, panel mounting or portable use; along with the well received G-10 Graphic Recorder.

Vari-L Company, Inc., Booth 3287
P. O. Box 1433
430 Fairfield Ave.
Stamford, Connecticut
▲ J. L. Kiser
New ovenized VARI-L electrically variable inductors for stabilization of center frequency. Examples of standard catalogue inductors and various special types, including packaged variable oscillators.

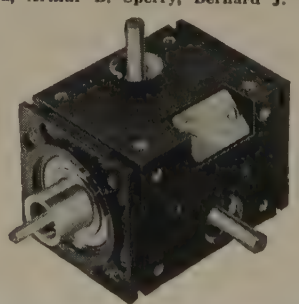
Vector Electronic Co.
3352 San Fernando Road
Los Angeles 65, Calif.
Booth 4050

▲ Ray R. Scoville, Merle M. Scoville

Transistor turret sockets, snap-open cases for transistor plug-in circuitry, experimenter's chassis, push-in terminals, rotoprobes, adapters, modular structures for circuitry.

Vectron, Inc.
1605 Trapelo Road, Waltham 54, Mass.
Booths 3106-3108

Andrew C. Bayle, C. W. "Bill" Brigham, ▲ Stewart K. Gibson, Wayne P. Gilbert, Robert C. Hilliard, Arthur B. Sperry, Bernard J. Warren



*SA30 microwave spectrum analyzers—including SA30X5 precision X-Band analyzer, SA30WR1 for 2,000 to 12,000 mc, and interchangable L, S, C, X, and K band RF heads. *Miniaturized sphere resolver.

Veeder-Root Inc., Booth 1823
70 Sargeant St.
Hartford 2, Conn.
T. Nelson, W. T. Heydt, R. W. Moller, A. T. Russo, R. G. Perfect, T. J. McLaughlin, T. L. Ellis, R. W. Russell, W. R. Soderquist
Exhibiting new remote data readout counters for telemetering, data conversion, automatic control, and remote recording. Also many counting instruments for military and other special counting requirements.

(Continued on page 428A)

Don't MONKEY AROUND



WITH YOUR
TRANSIT CASE
AND REUSABLE CONTAINER
PROBLEMS

Take them to Skydyne. For Skydyne engineers have years of experience in the design, development and production of reusable containers for electronic equipment. Their specialized "know how" brings practical, economical solutions.

What's more, they assume complete responsibility from design to delivery of your case, and let you concentrate on your own work. Thus, both the equipment and its transit case are ready at the same time.

It makes a lot of sense to find out more about this complete design and engineering service. Remember this: "Any equipment is only as good as its container which insures a safe arrival in good operating condition."

You can easily learn more about Skydyne's exclusive service and how it can help you. Write to:

SKYDYNE, INC.
River Road, Port Jervis, N.Y.

"Your Mark of Quality"

MINIMUM WEIGHT ★ Skydyne Inc MAXIMUM STRENGTH

SANDWICH MATERIAL — MOLDED FIBREGLAS



SIGNAL GENERATOR
SG-153 1800-4000 mc



HV INSULATION TESTER
T-4



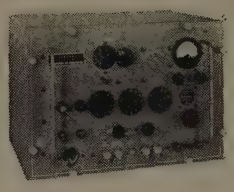
SIGNAL GENERATOR
SG-161 900-2100 mc



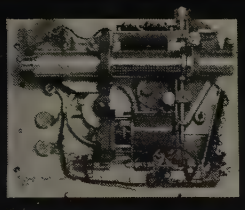
Q-PROBE
3-40 mc Circuit Probe



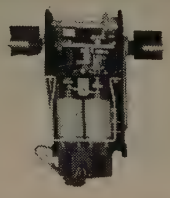
SWEEP GENERATOR
SG-132 15-400 mc



SIGNAL GENERATOR
SG-109 400-1000 mc



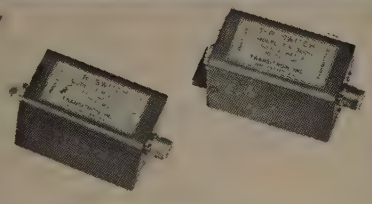
CAVITY OSCILLATOR ASSY.
2-4 KMC



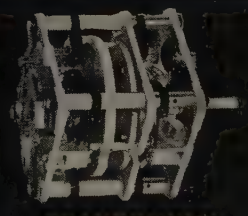
MULTISPEED AIRCRAFT
ACTUATOR T-113



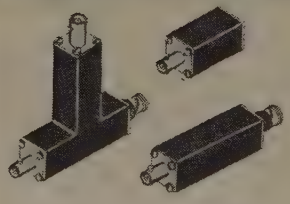
OSCILLATOR CAVITY ASSY.
1-2 KMC



T/R SWITCHES
Models 2000 & 3000



TRANSDUCER
TD 132



VHF ACCESSORIES

TRANSITRON INC.

186 GRANITE ST. MANCHESTER, N.H. (Subsidiary of Van Norman Industries)

Export Rep.—The Telesco International Corp., 36 W. 40th St., N.Y.C. 18

Canadian Rep.—Electrodesign, 736 Notre Dame St. W., Montreal, P.Q.

TRANSITRON, offers a complete line of precision VHF, UHF and SHF Signal and Sweep Generators for laboratory and production use. The exceptional accuracy of these generators allows precise measurements of standing wave ratio, receiver sensitivity, noise figure, image rejection, antenna characteristics and many others. A complete line of precision accessories including terminating detectors and attenuator pads for HF and VHF is available.

Other equipment developed and produced by **TRANSITRON** includes two-way mobile equipment, communications transceivers and test equipment such as the Q-Probe, T/R Switches, and H.V. Insulation Testers.

TRANSITRON also has extensive experience and facilities for the development and production of electronic and electro-mechanical devices to close tolerances and high standards of performance. Among these products are precision assemblies such as our large-deflection transducer, multi-speed aircraft actuators, and micro-wave components and assemblies.

Whether you require standard equipment, special equipment or development engineering, **TRANSITRON** can meet your needs with speed and efficiency.

Cunningham
CROSSBAR

Cunningham Presents

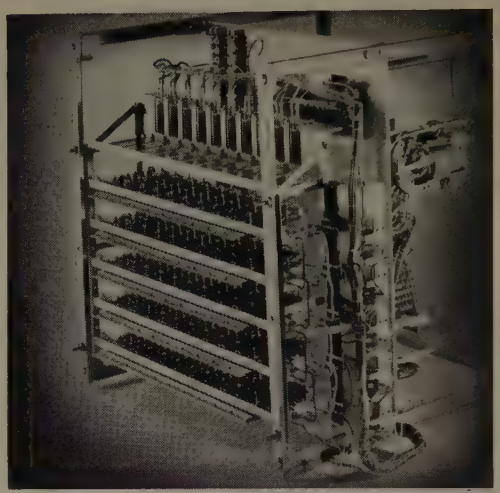
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A SELF-CONTAINED INSTRUMENT, SCANNING IN RESPONSE TO CONTACT CLOSURES.

- Adaptable to small or large systems —100 to 10,000 points.
- Flexibility of command.
- Contacts provided for controlling external devices at each point.
- Minimum space requirements.
- Handles low voltages (microvolt range) reliably—thermocouples.
- Very high leakage resistance.
- Applications in all low and medium voltage sampling.

See us at the IRE Show —Booth No. 2839.



Model 200SCIA scans sequentially 200 points and performs various auxiliary functions. Size 12" x 12" x 12"

JAMES CUNNINGHAM SON & CO., INC.
51 LITCHFIELD STREET ROCHESTER 8, N. Y.

natural **MICA**

single crystal strength



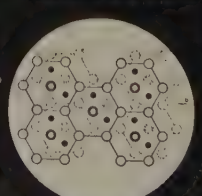
uniquely serves your DESIGN needs with . . .

- single crystal one-plane structure
- very high heat resistance (to 600° C)
- very high dielectric strength (1750 volts/mil) at as high as 800° F in capacitors
- power factor (1/Q): .0001 — .0004
- indestructibility by corona
- inertness to oils, solvents, moisture
- high hardness, strength, resilience
- indefinite storage ability
- can be fabricated to very close tolerances

. . . for such stringent applications as

- insulation between pulse transformer windings
- resistance windings
- high voltage, high current, high temperature, high stability capacitors
- klystron and waveguide windows
- windows in geiger tubes (0.2 mil thick)
- receiving tube spacers

Single layer construction of Indian Ruby Mica. $Al_2Al Si_3O_{10}(OH,F)_2K$.



Consult our engineers on your design projects. Write for quotations, literature, samples.

UMC QUALITY SERVICE

United Mineral & Chemical corp.
16-18 Hudson Street, New York 13

IRE Show, Booth 1321 and 1323.

Whom and What to See at the Radio Engineering Show

(Continued from page 426A)

Ventrak Corp., Booth 1430
11 West 42nd St.
New York 36, N. Y.

Thomas P. Dougherty, ▲ Robert L. Ringer, Jr.

Chassis Trak Slides, Basic and Detent, and handles with selection of locks and tilt control. Ventrak ventilated mounting racks single or in system banks.

Victor Adding Machine Co., Booth 1320
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Chicago 18, Illinois

Robert R. Howard, George W. Hasbach, Evan Ragland, ▲ James Masek

A *low cost 30 character per second Digital Printer and a new 100 KC adding and subtracting electronic counter are now available for automatic data processing.

Victoreen Instrument Co.
3800 Perkins Ave., Cleveland 14, Ohio
Booth 2231

R. L. Adams

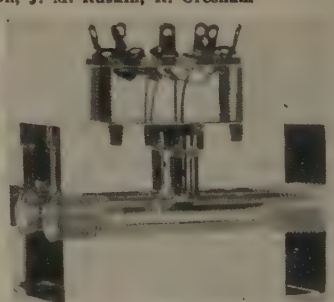


10 Plug-In Station Unit

Remote area radiation monitoring system based on modular unit concept. Can handle 20 stations, meets AEC requirements.

Victory Engineering Corp.
Springfield Rd. & Iorio Ct.
Union, N. N. J.
Booth 2230

▲ M. Sapoff, M. L. Miller, J. W. Kolessar, B. O. Moxon, J. M. Ruskin, R. Gresham



Gas Chromatography Cell

Gas Chromatography cells; bead, disc, rod, washer, thermistors, varistors, also gas analysis cells, thermistor hypodermic needles, thermistor telemetering probes, transistors and temperature compensators.

(Continued on page 430A)

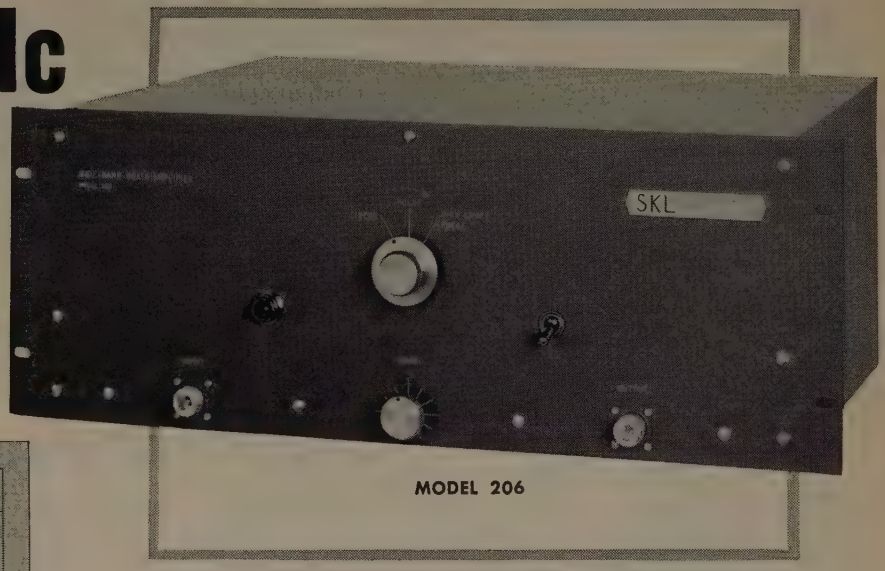
Cafeteria on Second Floor mezzanine. Take Elevator #16

SKL *introduces*

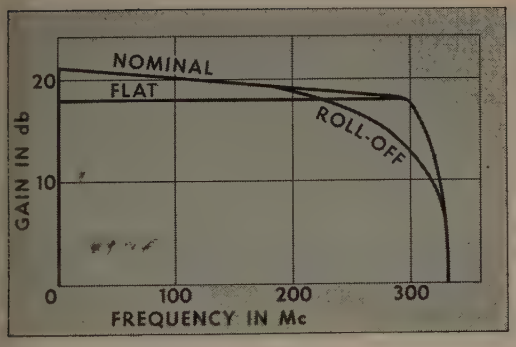
NEW ULTRA WIDE-BAND AMPLIFIER

for fast rise pulse reproduction

320 Mc



MODEL 206



Here is another advance in the art . . . Spencer-Kennedy's new Ultra Wide Band Amplifier, Model 206. Now for the first time fast-rise-time pulses can be faithfully reproduced by providing a stable 20 db gain over a *320 Mc band!* . . . Although nominal gain for Model 206 is 20 db, sloping to 18 db at 300 Mc and 14 db at 320 Mc, flat and gradual roll-off characteristics are readily available by means of small, inexpensive plug-in accessories (see curves above). Three output modes . . . linear, pulse and high pulse . . . are selectable by means of a front panel switch. Integral regulated power supply and rack mounting are also provided. Applications include amplification of the following: short fast-rise-time pulses from pulse generators, input to wide-band vacuum tube voltmeters, output of scintillation detectors, multi-channel VHF signals, wide-band IF signals, narrow band IF signals with wide range for choice of center frequency. Model 206 also serves ideally as a distribution amplifier for wide band receiving systems feeding multiple diverse channel receivers.

SPECIFICATIONS

Bandwidth:
300 Mc at 3 db point

Gain:
18 to 20 db depending on plug-in accessory

Rise Time:
Less than .002 μ seconds

Output:
Panel switch selects
(a) Linear: 5 volts, rms
(b) Pulse: 30 volts, negative
(c) High Pulse: Greater than 100 volts, negative, open circuit

Gain Regulation:
$\pm$0.5 db for line voltage between 105 and 125 volts

Gain Control:
Panel control varies gain 6 db

Phase:
Linear to 300 Mc

Impedance:
180 ohms input, 200 ohms output

Size:
19" wide, 8¾" deep, 7" high

Power Requirements:
115 volts, 60 cycles

Write for Bulletin 206-2

IRE Show — Booths 3502 and 3504

SKL
SPENCER - KENNEDY LABORATORIES, INC.
1320 SOLDIERS FIELD ROAD
BOSTON 35, MASS.

MINIATURE COMPONENTS

For Delivery From Stock
(MEET MIL-T-27A SPECIFICATIONS)

MINIATURE AUDIO TRANSFORMERS

Catalog No.	Input	Coupling	Power Level	Balanced DC Current	Unbalanced DC Current	Impedance Ohms	
			DBM	MA	MA	pri.	sec.
PMA-1	V		+8	0	0	50/200/500	60,000 center tapped
PMA-2	V		+8	0	0	4/8	
PMA-3	V		+8	0	0	50/200/500	
PMA-4		V	+8	0	0	15,000	
PMA-5		V	+8	2	2	15,000	
PMA-6	V		+8	0	0	15,000	50/200/500
PMA-7	V		+8	2	2	15,000	
PMA-8	V		+8	2	.25	30,000 ct	
PMA-9		V	+8	0	0	60,000	
PMA-10		V	+8	0	0	50/200	

All units ±2 DB 30 to 20,000∿; PMA 5 and 7 ±2 DB 200 to 10,000∿. Case size 15/16"D x 1½" high, flanges 1½" long.

TRANSISTOR TRANSFORMERS

Catalog No.	200 to 15,000	300 to 15,000	Unbalanced DC Current	Max. Power Out	Impedance Ohms	
	DB	DB	MA	W.	pri.	sec.
TMA-1	±1		0	.25	500	500
TMA-2		±2	3	.25	50K	500
TMA-3		±2	3	.25	50K	6
TMA-4		±3	1	.25	100K	1.2K ct.
TMA-5	±2		3	.25	25K	1.2K ct.
TMA-6		±2	3	.25	50K	1.2K ct.
TMA-7	±1		4	.25	600/150	1.2K ct.
TMA-8	±2		3	.25	25K	600
TMA-9	±1		1	.25	4K ct.	600/150
TMA-10	±2		10	.25	2K	3.2
TMA-11	±1		1	.25	4K ct.	3.2
TMA-12		±2	4	.25	20K	50
TMA-13		±2	8	.25	1K	50
TMA-14		±2	0	.10	100K	1K
TMO-15		±2	1	.04	20K	50
TMO-16		±2	1	.04	20K	600
TMO-17		±2	3	.06	1K	50
TMO-18		±2	0	.10	100K	1K
TMA-19	±2		20	1.	1K	3.2

Case size 1"D x 1.5" high, flanges 1⅜". Specify TMO for open, TMC for encapsulated units.

MINIATURE HIGH Q TOROIDS

Cat. No.	Ind. MHY	Cat. No.	Ind. MHY	Cat. No.	Ind. MHY	Cat. No.	Ind. MHY
to 15 KC		10 to 50 KC		30 to 75 KC		50 to 200 KC	
F2050	1.	F2100	0.1	F2140	0.1	F2180	0.1
F2051	3.	F2101	0.2	F2141	0.2	F2181	0.2
F2052	5.	F2102	0.3	F2142	0.3	F2182	0.3
F2053	10.	F2103	0.4	F2143	0.4	F2183	0.4
F2054	15.	F2104	0.5	F2144	0.5	F2184	0.5
F2055	30.	F2105	1.0	F2145	1.0	F2185	0.6
F2056	50.	F2106	2.0	F2146	2.0	F2186	0.7
F2057	75.	F2107	3.0	F2147	3.0	F2187	0.8
F2058	100.	F2108	4.0	F2148	4.0	F2188	0.9
F2059	150.	F2109	5.0	F2149	5.0	F2189	1.
F2060	200.	F2110	7.5	F2150	7.5	F2190	2.
F2061	300.	F2111	10.	F2151	10.	F2191	3.
F2062	400.	F2112	15.	F2152	15.	F2192	4.
F2063	500.	F2113	20.	F2153	20.	F2193	5.
F2064	750.	F2114	30.	F2154	30.	Case size: ¾"x11/32" x25/32h.	
F2065	1,000.	F2115	50.	F2155	50.		
F2066	1,250.	F2116	75.	F2156	75.		
F2067	1,500.	F2117	100.	F2157	100.		
F2068	1,750.	Encapsulated 1"dx⅞"h. When ordering hermetically sealed units add H, encapsulated units MR to Cat. No.					
F2069	2,000.						

Send for NEW 48 page transformer catalog. Also ask for complete laboratory test instrument catalog.

FREED TRANSFORMER CO., INC.

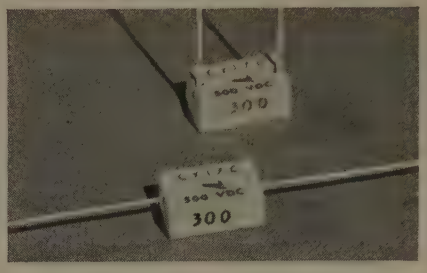
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Whom and What to See at the Radio Engineering Show

(Continued from page 428A)

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Box 544, Bridgeport 1, Conn.
Booth 2409

Frank Baron, Bob Helmling, John Jorgensen, Bob Millar, ▲ Al Takacs, ▲ Bart Weller



Type AR Ceramic Capacitors

VITRAMON capacitors, formerly available only with axial leads, now give more flexibility with leads for either AXIAL or RADIAL applications of this porcelain component.

Wales-Strippit Co., Booth 4010
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North Tonawanda, N. Y.

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Printed circuit punching machine in operation, complete line of press tooling for punching and notching radio, TV and electronics chassis, control panels, switchboards and instrument cabinetry.

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145 West Hazel Street
Inglewood, Calif.

Wes. L. Kirchoff, Howard Schoenduve, David Sonkin, Herb Freudman

Transistorized computer circuitry, plug-in circuits & resin embedments, including counters, multivibrators, pulse generators, wave formers, triggers, gates, amplifiers & other unitized circuitry.

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Soldering Products. Irons—Guns—Pencils: AC or DC Blow Torches—Engineering Service.

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Brooklyn 16, N. Y.

Harold Rubenstein, Jack Walter, Jack Sternberg, Paula Torkildsen, Nat Eagle, Marilyn Grimaldi, Ada Parker, Mary Low

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High altitude ruggedized aircraft telephone plug. Standard telephone plugs and jacks, RF coaxial connectors and fittings. Waveguide Adapter. Custom Engineered unique connectors.

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Cambridge 41, Mass.

▲ A. Wang, ▲ G. Y. Chu

Programmed Pulse Generator*. Automatic TV Synchronizer*. Magnetic Shift Register*.

(Continued on page 431A)

* Indicates new product
▲ Indicates IRE member

Electomic

CLUTCHES, BRAKES, COMBINATIONS



TORQUE: 80 oz. in (proportional to excitation)

SPEED: 5,000 rpm (continuous cycling)

SLIP: up to 100%

RESPONSE: 2-3 milliseconds (depending on application)

SIZE: 1.5" diameter

WEIGHT: 6 oz.

TYPE: Dry Iron Powder

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(Continued from page 430A)

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See *MIL-R-26C Resistors* in all Styles and Sizes; VITROHM power wire-wound Resistors; Ring Rheostats, Relays; Contactors; Lighting Controls. See *Miniature Power Resistor . . . 3 Watt AXIOHM.*

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Booths 1902-1904

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See oscilloscope checking *Hamilton Electric Watch. The manufacturer of famous Pocketscopes and Panelscopes show other new ideas in oscilloscope applications.

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James A. McGregor, Robert H. Koenig, Robert H. Klarer, Walter Specht, John Morris, Barbara Mooney

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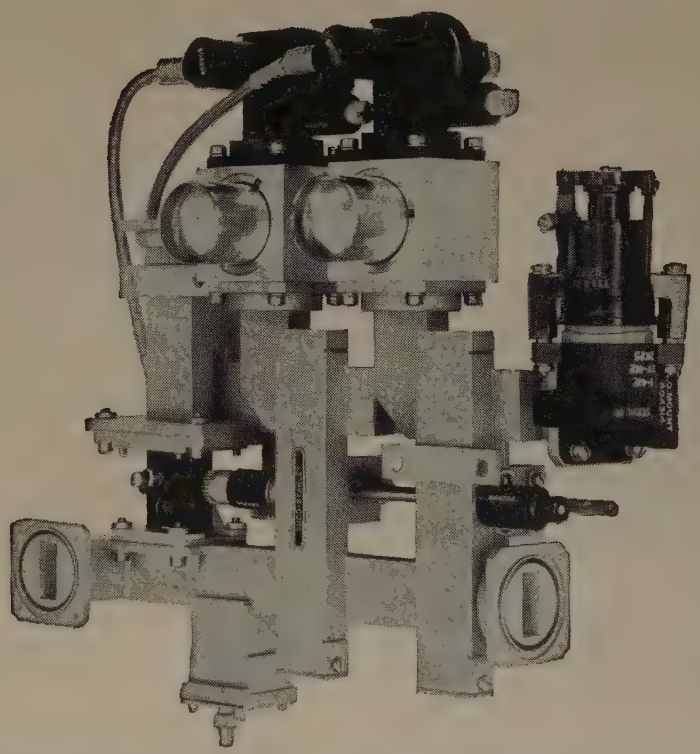
(Continued on page 432A)

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(1) Exclusive new casting process now produces waveguide assemblies without machining and brazing.

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RF HEAD (cast section shown unpainted)

You can depend on Budd•Stanley engineering know-how, manufacturing methods and experience to produce microwave transmission equipment to your specific requirements.

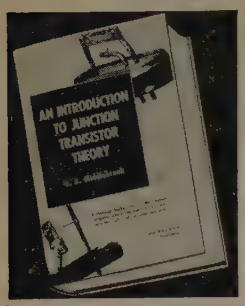
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By ISAAC FERN KINNARD, General Electric Co., with 14 contributors. Covers the theory of measurements, measurements of electrical quantities, and measurements of non-electrical quantities by electrical means. 1956. 600 pages. 417 illus. $15.00

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(Continued from page 431A)

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122 Cutter Mill Road
Great Neck, N. Y.

H. A. Wheeler, D. Dettinger, F. H. Williams, N. A. Spencer, P. A. Loth, P. W. Hannan, H. W. Redlien, H. L. Bachman, E. H. Kraemer, R. D. Wengenroth

Microwave Engineering—Design—Consultation.

Roger White Electron Devices, Inc., Booth 3606
Fourth Ave.
Haskell, N. J.

Roger E. White

Noise sources, microwave gas control tubes, traveling wave amplifiers, oscillators, tubes.

Whittaker Gyro, Booth 2128

Jack Baker

Oscillogram reader, four digit teleducer, complete line of gyros (exploded and mounted, uncovered, and cased), marker pulser and a variety of precision components to include delay lines, relays, pulse and switches.
See Telecomputing Corp. & Brubaker Electronics.

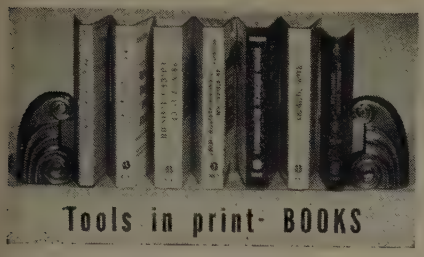
Who's Who in Electronics & Military Electronics, Booth 4406

See: Electronic Periodicals, Inc.

A complete list of registrants at the IRE National Convention and Radio Engineering Show, brought up to date twice daily, is posted on the west wall at the back of the first floor.

John Wiley & Sons, Inc.
440 Fourth Ave., New York 16, N. Y.
Booth 4322

Walter G. Stone, Charles B. Stoll, Robert J. Tilley, Albert M. Dowden, Benjamin B. Thelmin, Thurmond R. Poston



TOOLS IN PRINT—BOOKS. Publishers of scientific and technical books for a century and a half, this year Wiley will display an even greater number of basic and advanced books in all areas of radio engineering.

Winchester Electronics, Inc., Booth 2836
Willard Road
Norwalk, Conn.

Kenneth Floyd-Jones

Environmental connectors, plus a comprehensive line of electronic connectors for internal and external applications: miniature, subminiatures, hermetics, quickdisconnects, printed circuit connectors, standoff and feedthrough terminals.

Wind Turbine Co.
248 E. Market St.
West Chester, Pa.

Booths 1712-1714

Davis B. Oat, ▲ A. C. Veldhuis, C. K. Hutchison, F. H. Lukens

Exhibiting our *type 4600 TRYLON Ladder Tower and prefabricated ground mat made of copperweld wires with various wire spacings.

Yardney Electric Corp.
40-46 Leonard St., New York 13, N. Y.
Booth 2127

Martin E. Kagan, ▲ Paul L. Howard, Saul Padwo, T. B. Thompson, Col. George F. Hartman



Model #SC5-HR Lighted Rechargable Battery

Latest advances in primary and secondary alkaline batteries. Introducing highly efficient Nickel-Zinc and Silver-Cadium (SILCAD) systems.

Zell Products Corp., Booth 4045
276-80 Main St.
Norwalk, Conn.

S. Young

Kovar stampings and hermetic seal components.

Zephyr Mfg. Co., Inc., Electronics Div., Booth 4522
201 Hindry Ave., P. O. Box 759
Inglewood 1, California

Will M. Tompkins

Electronic micro-brazer & accessories (soldering equipment).

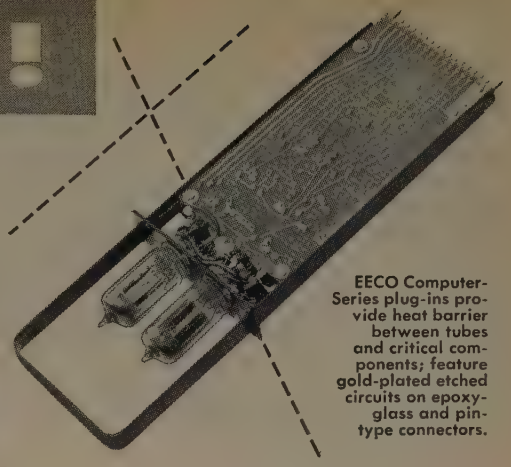
* Indicates new product.

▲ Indicates IRE member.

NEW!

EECO COMPUTER-SERIES PLUG-INS

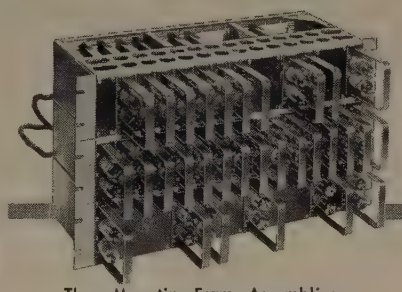
...a refinement of the building-block concept to a degree hitherto unknown, with each circuit a complete off-the-shelf packaged function.



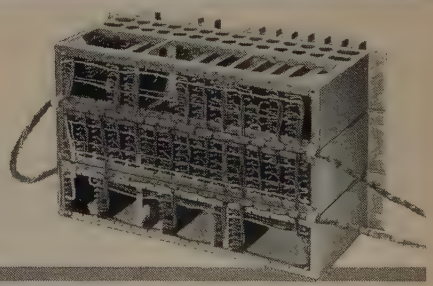
EECO Computer-Series plug-ins provide heat barrier between tubes and critical components; feature gold-plated etched circuits on epoxy-glass and pin-type connectors.

Originally developed for EECO custom systems and proven in critical use, this compatible series of digital and logic circuits is now available to the industry. Meet your project delivery schedules by reducing system-development time to a bare minimum and virtually eliminating drafting and layout time.

PERFORMANCE EECO Computer-Series plug-ins are performance engineered for application where ultra-conservative design at the component level is essential because of system complexity. System prototypes can generally be built directly, without need for the "breadboard" stage.

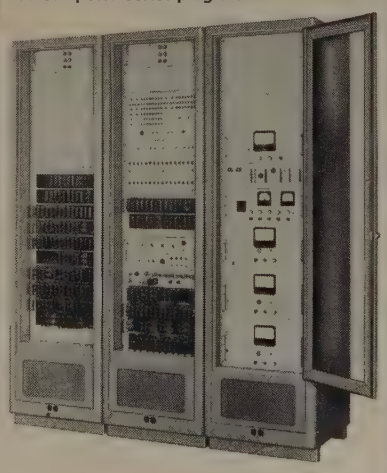


Three Mounting Frame Assemblies were stacked to house this Output Shift Register. Each Mounting Frame accommodates 15 plug-ins, is 3½"x19" for installation in 19" rack.



Rear view of Output Shift Register shows simplicity of point-to-point wiring.

Quick-Look section of EECO-built Project Datum installation at Edwards Air Force Base shows typical modular assembly of Computer-Series plug-ins



* **QUICK FACTS:** Tube dissipation de-rated 75%; cathode current de-rated 50%. 1% components used where 5% required and 5% where 10% required. Reliable operation with ±20% change in filament voltage, 30% change in tube transconductance. Isolating diodes on multiple inputs eliminates crosstalk. Low output impedance—in general, cathode follower. (One flip-flop will trigger another at the end of a 50-foot length of twisted pair!) Signal levels clamped. Computer-type tubes. Circuit trouble-shooting already done; layout basically completed. Packaging, heat-barrier, and ventilation problems solved. In-circuit test fixture available.

CIRCUITS You can concentrate on the design of *systems*, knowing you have available a full line of reliable, tested, and proven circuits, including:

Flip-Flops	**Quadruple Cathode Followers**
Shift Register Elements	**One-Digit Adder Matrixes**
DC "NOT" Circuits	**One-Digit Subtractor Matrixes**
Delay Units	**One Shots**
Pulse Mixer Amplifiers	**Neon Drivers**

plus 28 Diode Logic Units incorporating "And" and "Or" circuits. In addition, EECO stands ready to design diode logic circuits and produce plug-in units to yield any equation you may require. In short, custom-built logic to order—quickly!

*Detailed information on new Computer-Series plug-ins, as well as on Standard-Series plug-ins, Systems Development Racks, Power Supplies, D-C Amplifiers, and other EECO products is available in Catalog No. 856-A. Write for your copy—today.

ELECTRONIC ENGINEERS AND PHYSICISTS—*EECO offers immediate opportunities for qualified engineers in the transistor, amplifier, data-handling, pulse, timing, and systems-design fields. Send a resume of your qualifications to R. F. Lander, Dept. CS.*

ENGINEERED ELECTRONICS Company

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a subsidiary of Electronic Engineering Company of California

506 EAST FIRST STREET SANTA ANA, CALIFORNIA

That new idea demonstrated: Reliability in action...at the IRE Show...

New ideas stem from seeing the BJ Electronics Vibrotron Transducer sensing pressure variations and feeding frequency changes to a remotely-located BJ Digital Data System. When reliability and accuracy are imperative, the Vibrotron Transducer out-performs all similar devices. Utilizing a stretched vibrating wire tuned by a diaphragm, the Vibrotron Transducer generates its own precision measurement signals which are transmitted without loss of accuracy to the BJ Digital Data System. The System then directly reads-out signals in 4 digit numbers. These values can then be fed to a recording device or used to initiate control action.

At the Annual IRE Convention... Booth Number 3506...other product displays by the BJ-75 (AN/-USM-16) Multi-purpose Signal Generator, combining functions of sweep, FM, AM and pulse-type generators . . . and the Detectolab product line of nuclear instruments such as the DZ 21 medical Spectrometer.



BJ *Reliability You Can Count Upon*
ELECTRONICS

BW
BORG-WARNER CORPORATION
3300 NEWPORT BOULEVARD
P. O. BOX 1679, SANTA ANA, CALIFORNIA

News-New Products

(Continued from page 29A)

Hermetic Seal Terminals Bulletin

International Resistance Co., 401 North Broad St., Philadelphia 8, Pa. now offers miniature units as Type Lt, the terminals are designed to meet all military and commercial application requirements.

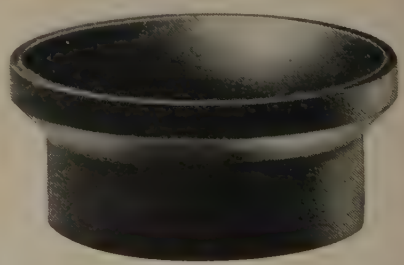
A body of molded Fluorocarbon Plastic* insulates the solder seal ring from the fee-through lead. Type Lt's are unaffected by high humidity and are chemically inert to organic solvents, acids, alkalies, oils and fumes. Physically tough, they will withstand usual production handling and will not crack or craze. They successfully overcome electrolysis under high dc voltage, low corona breakdown voltage, low operating temperatures, inconsistent hermatic seals and similar limitations often found in other types of hermetic sealing terminals.

The IRC Type Lt Terminal is specifically designed for requirements such as superior insulation resistance, zero moisture absorption, high arc-over resistance, wide temperature range and thermal shock, and miniaturization.

*Polymonochlorotrifluoroethylene

Light Weight Ferrite Core

Development of a new method of molding full-round ferrite deflection yoke cores by **Allen-Bradley Co.,** 136 West Greenfield Ave., Milwaukee 4, Wisc., has led to still another improvement, a flared ferrite core for use with the new 110° picture tubes.



The new flared yokes make possible a weight reduction of 30 percent over conventional cylindrical cores heretofore used for these new picture tubes. The reduction in material comes from shaping the outer surface so that the cross section is approximately uniform from top to bottom.

(Continued on page 436A)

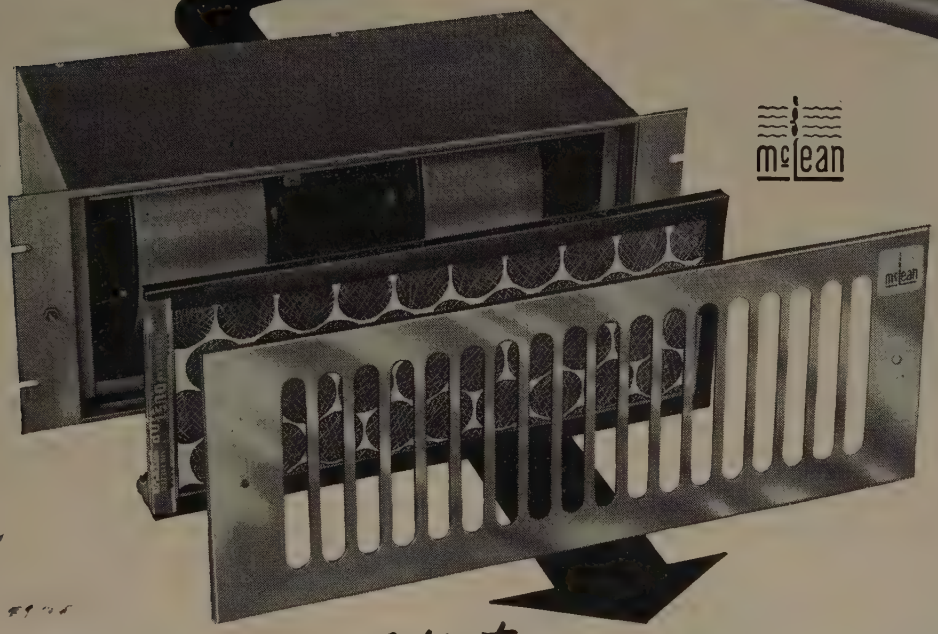
Cool That Cabinet—Save Sensitive Components

GENERAL FEATURES

- Pressurizes Cabinet With Filtered Air
- Rubber Isolated Motors For Quieter Operation
- Widely Accepted for Use In Military Equipment
- Maximum Air Delivery For Efficient Filter Action



PHOTO COURTESY APPLIED SCIENCE CORP OF PRINCETON



ADDITIONAL FEATURES FOR BLOWER TYPE UNITS

- Provide Better Air Delivery Against Pressure
- Provide Quieter Operation Against Pressure
- Higher Air Velocity For Faster Cooling
- Air Flow Maintained With Dirty Filter
- Duct Connections Can Be Made If Desired

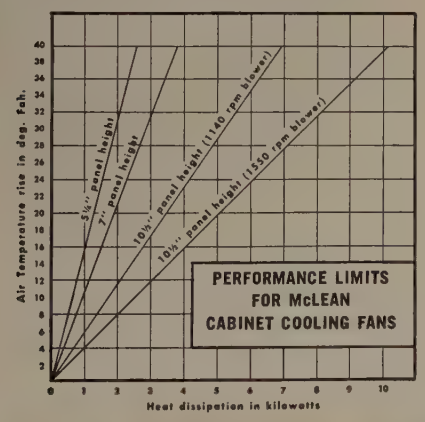
use McLEAN *Cabinet Cooling* FANS and BLOWERS*

*Pat. Applied For

RACK MOUNTED FOR EASY ASSEMBLY • FIT STANDARD 19" RACKS

THREE STANDARD MODULAR PANEL HEIGHTS COVER WIDE RANGE OF AIR DELIVERIES

Excessive or fluctuating temperatures in electronic racks make thousands of tubes die young . . . make crystals, transistors and sensitive electronic equipment perform erratically. System failure at critical times is disastrous . . . replacement costs are high. That is why leading manufacturers install McLean Fans and Blowers in Computers, Control Systems, Data Processing Systems, etc. These small packaged units pressurize the cabinet with cool filtered air, keeping dust out. They are complete in one unit and ready for use. Standard RETMA notching allows mounting on rack . . . no cutting or fitting is necessary. All units contain an easily replaceable filter. Smart stainless steel grilles add beauty and eliminate the necessity of matching cabinet finishes.



SPECIFICATIONS

PANEL HEIGHT	MODEL	DEPTH	CFM	REMARKS	TYPE
5¼"	2A300	7½"	80	Standard Rack Mounting	Blower
	2E300	7½"	80	For Trim Strip Racks	Blower
	2B300	7½"	150	Basic Model	Blower
	3E40	5⅞"	190	For Special Clearance	Propeller
	2P408	11⅛"	300	Inside Height 7"	Blower
7"	2E55	8¼"	250	Basic Model	Propeller
	2E408	10"	300	Basic Model	Blower
	2A408	8¼"	300	No Projecting Outlets	Blower
	2E408V	8¾"	300	Vertical Discharge	Blower
	2E55H	8¼"	310	400 cps Model	Propeller
10½"	2E80	8⅛"	500	Basic Model	Propeller
	2B610	13¼"	550	Slow Speed Model	Blower
	2A610	13¼"	800	22" Rack Width	Blower
	2E610	13¼"	800	Basic Model	Blower

MODIFICATIONS OF ABOVE MODELS CAN BE MADE TO 24" OR SPECIAL WIDTH RACKS TO ORDER

FREE OUR NEW CONDENSED CATALOG! SEND FOR IT TODAY.

McLEAN ENGINEERING LABS. PRINCETON, NEW JERSEY
PHONE: PRINCETON 1-4440

LOS ANGELES: RICHARD C. DUDEK, 407 No. Maple Dr., Beverly Hills • Bradshaw 2-8097

See us at Booth 4420, IRE Show.

Lerco

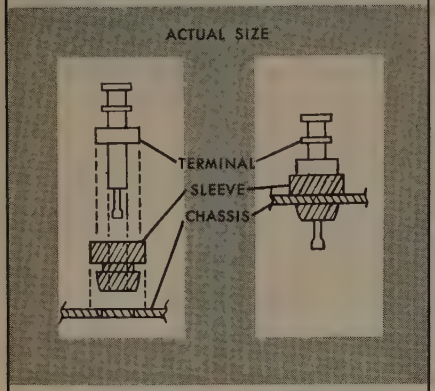
electronic hardware

●

now...

TEFLON®

SNAP-LOCK *terminals*



- *new principle (patent pending) eliminates terminal boards*
- *terminals install directly in chassis*
- *provides ground ring for sensitive circuits*

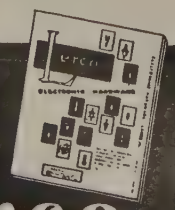
Lerco's new Teflon insulated terminals make possible new design methods which eliminate terminal boards. The terminals, individually insulated from the metal by Teflon, may be installed directly in the chassis. First, the Teflon sleeve is snapped through a hole in the chassis. Then the terminal is inserted and swaged over the insulator to lock the assembly solidly in place. Lerco Teflon insulated terminals will withstand severe shock and vibration conditions.

The Lerco terminals (patent pending) are now produced in sizes for .035, .050, and .062 thickness material. Illustrated above is Number 4075. For other variations now available and for further information, write for complete brochure.

® Dupont trade mark

ALWAYS CALL LERCO FOR

- **Diode clips • Terminals**
- **Terminal boards**
- **Taper pin terminals**
- **Stand-offs • Plug assemblies**
- **Inserts • Sockets**
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Lerco

ELECTRONICS, Inc.

501 South Varney Street

Burbank, Calif. • Victoria 9-5556

News-New Products

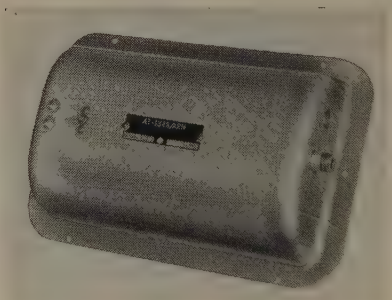
(Continued from page 434A)

The new flared cores for the 110° picture tubes are available in Class WO-1 ferrites, a material of uniform permeability and flux density.

The cores are made as a full 360° ring, then "cracked" by a special process into two mated halves, which are rejoined and mechanically held together for shipping. The "full-round" construction has also the advantage that there is no need for grinding and matching, as is required when quarter sections are used.

Marker Beacon Antenna

Telectro Industries Corp., 3516 37th St., Long Island City 1, N. Y., announces the introduction of Model AT-134, 75 MC marker beacon antenna designed specifically for use with aircraft type marker beacon receivers. The model AT-134 is installed by flush mounting it on the bottom of an airplane fuselage.



The external arrangement of the Model AT-134 is a flanged deep drawn aluminum alloy case forming the antenna cavity with the slotted shaft of the variable loading capacitor extending through the closed top of the case to permit screwdriver adjustment and tuning. The flanged bottom, or airplane surface side of the antenna, as furnished, is open. On the short sides of the cavity are the receptacle for the connection of the lead-in, and an 18 MM threaded hole. The hole may be used for antenna dehydration.

The internal arrangement includes a shunt-fed, bent-channel receiving element, top loaded by a small variable capacitor in parallel with a 25 $\mu\mu$f temperature compensated fixed capacitor.

Dimensions are: $11\frac{3}{4}$ long by $7\frac{3}{4}$ wide by $3\frac{1}{2}$ inches high.

(Continued on page 437A)

NEW

High Power

10 Watt

SILICON TRANSISTOR

See them at Booths

2115 - 2117

PRECISION ELECTRICAL EQUIPMENT

Bogue

SINCE 1892

BOGUE ELECTRIC MFG. CO.

PATERSON 3, NEW JERSEY

Announcing the

NEW



MAGTROL SERVO DYNAMOMETER

Meets critical requirements for testing free running speed, without external drag on test motor; any torque and speed in motor range; and stall torque of motor. Magtrol Servo Dynamometer consistently indicates time shaft speed, without calibration, at accuracies of ½ of 1% or better.

See it in Action at Booths 1230 and 1232

or write for Catalog CBD

MAGTROL 38 Virginia Place Buffalo 2, N.Y.

News-New Products

(Continued from page 436A)

Remote Position Control

The Dialtrol, a new high accuracy, low cost "follow-up" type of remote control, has been announced by **The Jordan Co.,** 3235 W. Hampton Ave., Milwaukee 9, Wis.

A Vernier dial on the face of the control is set to establish accurately the desired position of a valve, variable speed drive control, jack, rheostat, and so forth. A control motor, with built-in or externally driven potentiometer, adjusts the valve, drive, jack, etc. until the proper setting is obtained. The Jordan Shaftrol, a shaft mounted control gear motor with the Dialtrol but other gear motors connected to suitable potentiometers may be used.

Full scale follow-up accuracy of ± 0.5 per cent is standard but precision multi-turn potentiometers may be used to provide accuracies of 0.04 per cent. Indication by counter rather than vernier may then be provided.

The Dialtrol incorporates adjustable anticipation to slow down the control motor as the desired setting is approached. In this way "over travel" is prevented and the desired setting is arrived at without hunting. The "anticipation" adjustment and an "accuracy" adjustment are located behind the hinged front panel The accuracy adjustment permits introduction of lost motion which may be desired for certain applications such as dancer roll control

Depending on the speed of the control motor the follow-up control may take a minute or more or may be almost instantaneous, taking less than a second. The Dialtrol provides direct control for motors up to $\frac{1}{8}$ hp and controls motors up to 50 hp through a reversing starter. The Dialtrol may be located several 1000 feet from the control motor.

NEMA 1 enclosure is standard but totally enclosed and explosion proof enclosures are available. Standard Dialtrols operate on a single phase, 60 cycle, 110 volts with operation on other supplies furnished as "specials." A 5 wire conductor connects the Dialtrol to the control motor and follow-up potentiometer.

(Continued on page 438A)



RADIO FREQUENCY
CALORIMETER

DC to 4000 Mc • 10 to 150 Watts
CONSTANT FLOW TYPE

- Does not use flowmeters
- Does not use thermometers
- Does not require any flow adjustment

SOLD ON A TRIAL BASIS
because we are so sure of its performance.

The Simplest Calorimeter to Operate

The only control is the on and off switch. Flip it on, connect the radio frequency power and watch the meter needle climb to the correct value for approximately one minute. Then read power directly on meter.

Accuracy : 5%
Power Supply : 105 to 120 V., 60 cps
Measuring Time : One Minute

SEE US AT THE
IRE SHOW
BOOTH 3316

Other Calorimeters covering the range of DC to 12,000 Mc, coaxial and waveguide, low and high power available.

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208 RIVER STREET • RED BANK, NEW JERSEY • Phone: SHadyside 1-0404

Eliminate Rhodium Plate Rejects!



Sel-Rex only RHODEX

produces compressively stressed deposits

assuring crack-free, peel-free service. Here's proof! The photograph demonstrates the high tensile stress of conventional rhodium electroplate and the CS of RHODEX. Dissolving the basic metal caused the conventional rhodium electroplate to disintegrate into small crystalline flakes. The Sel-Rex RHODEX electroplate remained unimpaired, and in a continuous film. RHODEX does not peel or crack regardless of thickness! Write for details.

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Sel-Rex® SEL-REX CORPORATION
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CONNECTORS...

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Automatic

Highest standards of quality. Modern high speed automatic machinery, and up-to-date production procedures, based on over 15 years experience in the manufacture of precision parts for the Army, Navy, Air Force and Atomic Energy Commission.

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COAXIAL RELAYS · COAXIAL SWITCHES
COAXIAL CABLE ASSEMBLIES · DIRECTIONAL COUPLERS · INSULATED CONNECTING RODS AND SHAFTS · POWER PLUGS · AUDIO PLUGS · BAYONET LOCK AND PUSH ON SUB-MIN CONNECTORS

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Automatic
METAL PRODUCTS CORP.
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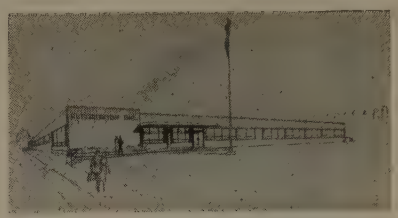
News-New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 437A)

New Hetherington Plant

Work is under way for a new one-story, 16,200 square-foot building for **Hetherington, Inc.** Site of the activity is a six and three-quarter acre plot on Hook Road in the suburban Philadelphia community of Folcroft, Pa.—just one-half mile from Hetherington's present Sharon Hill plant.



According to Joseph Schellman, Hetherington president, the Folcroft plant will provide urgently needed extra room in all departments to meet the growing demands of the aviation, electrical and electronic industries. The new air-conditioned building will house administrative, sales, and engineering offices as well as testing and assembly departments. Basic parts manufacturing for Hetherington's special-purpose switches and indicator lights will remain in the Sharon Hill plant.

New Capacitors

A new series of high-capacitance electrolytic capacitors designed especially for filtering power supplies in digital computers and other applications, which require an unusual degree of long and trouble-free service life, is now commercially available from the **Sprague Electric Co.,** Marshall St., North Adams, Mass.



Known as Sprague Type 32D, these capacitor designs have in a large measure, been developed

(Continued on page 439A)

WIDE-RANGE
FREQUENCY METER
85-1000 MEGACYCLES

TS-175A/U

Government Approved Calibration Accuracy: .005%
Stability: .0025%
Resettability: .0025%

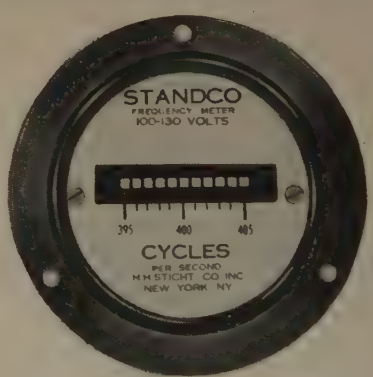


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A VERSATILE PRECISION MEASURING INSTRUMENT *Recommended Applications:*

- Precise Measurements of Frequencies
- Production Testing
- Alignment of Transmitters and Receivers
- Laboratory Testing
- Portable Field Testing
- A Secondary Frequency Standard
- Signal Generator Calibration
- U.H.F. and V.H.F. Television Alignment

COLORTONE
ELECTRONICS, Incorporated
200 Frank Road, Hicksville, L. I., N. Y. HI 3-2121



"STANDCO"
VIBRATING REED
FREQUENCY METERS
ACCURACY ±.5%
RUGGED—DEPENDABLE

Normal Frequencies:
25, 50, 60 or 400 cycles
Special Ranges:
from 15-1500 cycles

AVAILABLE IN FOLLOWING TYPES:

- **PANEL MOUNTING:** 3½" flush bakelite, metal or hermetically sealed cases. Meet all MIL specs.
- **SWITCHBOARD MOUNTING:** 7¼" round surface, or 4½" square semi-flush cases.
- **PORTABLES:** In large or small cases.

See these meters at Booth #3044

HERMAN H. STICHT CO., INC.
27 PARK PLACE, NEW YORK 7, N. Y.

(Continued from page 438A)

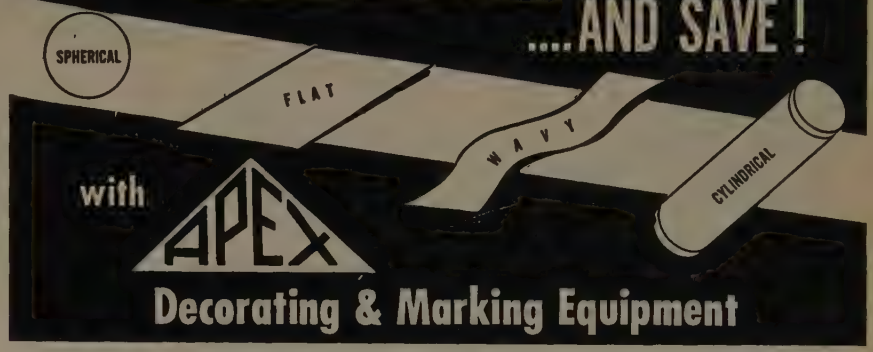
from the telephone quality electrolytic capacitors which have been produced by Sprague for more than twenty years. A complete line of ratings ranging from capacitances as high as 3 600 μf at 5 volts to 700 μf at 350 volts dc working are listed in the new Engineering Bulletin 3441. The bulletin also describes the severe performance requirements which these capacitors will withstand. Copies are available on letterhead request to Sprague's Technical Literature Section.

Filament-Focus Power Supply



Developed by **Levinthal Electronic Products, Inc.,** 979 Stanford Industrial Park, Palo Alto, Calif., for klystrons with bombarded cathodes, the Model PC51 Power Supply provides 0–3 kv dc at 0.9 amperes with less than 0.5 per cent ripple, 0–20 volts ac at 60 amperes and 0–750 volts dc at 20 ma. All three supplies are insulated at 30 kv dc above ground for operation with a separate beam power supply. Meters are available for measuring bombarder voltage and current, filament voltage and current, and focus-electrode voltage and current. The unit is completely protected by interlocks and has appropriate time-delay and sequential operation built in, to prevent operation of any supply before the filament is on and hot and the bombarder supply is on and up.

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DIRECTLY ON YOUR PRODUCT
....AND SAVE !



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Decorating & Marking Equipment

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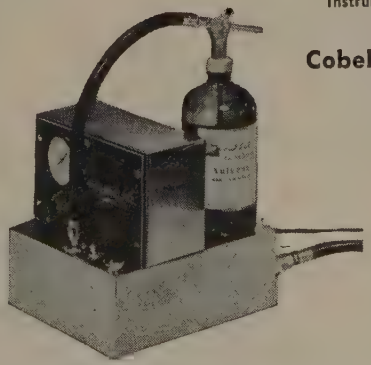
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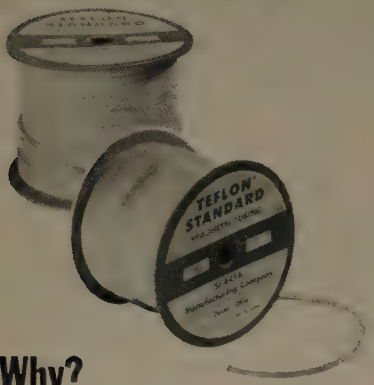
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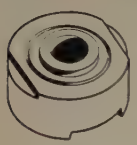
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Cantlon, C. F., Hamilton, Ont., Canada
Caywood, R. W., Reading, Mass.
Chimera, V. J., Akron, Ohio
Clapp, R. W., Manhattan Beach, Calif.
Corderman, C. L., Winchester, Mass.
Couden, D. V., Albuquerque, N. Mex.
Dambach, R. A., Cleveland, Ohio
Dern, H., Englewood, N. J.
Frenkel, L. J., Jr., Albuquerque, N. Mex.
Gikow, E., West Long Branch, N. J.
Hackley, G. E., Los Altos, Calif.
Happ, W. W., Mountain View, Calif.
Hill, C. R., Los Angeles, Calif.
Hime, N. S., Cedar Rapids, Iowa
Huebscher, H., Flushing, L. I., N. Y.
Jacobson, R., Pacoima, Calif.
Kalson, N. H., Encino, Calif.
Kerr, J. S. S., Los Angeles, Calif.
Kodis, R. D., Providence, R. I.
Kowitz, A. E., Chicago, Ill.
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Lowery, W. E., Wayland, Mass.
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Mortenson, K. E., Troy, N. Y.
Nishio, H., Yokohama, Japan
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Bowman, R. L., Bethesda, Md.
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(Continued on page 441A)

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Schmidt, H. J., Troy, Ohio
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Shimizu, J. K., Palo Alto, Calif.
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Weigel, E., Milwaukee, Wis.
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Winter, R. E., Springfield, Va.
Wright, C. P., Seattle, Wash.
Yahalom, J. Y., Chicago, Ill.
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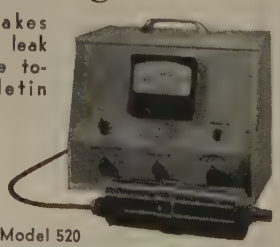
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Anderson, J. A., Rochester, Minn.
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(Continued on page 444A)

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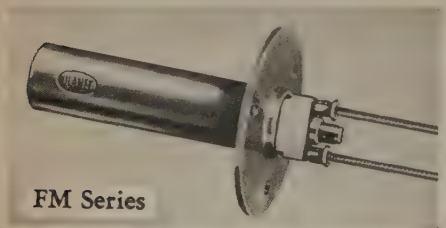
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AGE:
15 years in missiles; 37 in aircraft.

EDUCATION:
An engineering company managed by engineers — such as Donald W. Douglas, B.S., Aeronautical Engineering (M.I.T.); F.W. Conant, B.S., Civil Engineering (Cornell); and A. E. Raymond, B.S., Mechanical Engineering (Harvard), M.S., Aeronautical Engineering (M.I.T.), and Ph.D. (Hon.) (Polytechnic Institute of Brooklyn) — and with key staff positions held by graduate engineers, physicists and mathematicians, many with advanced degrees.

EXPERIENCE:
Pioneers in missile research development and production since 1941.

Major contractors for air-to-surface, surface-to-surface, air-to-air and surface-to-air missile systems.

Designers of auxiliary equipment to transport and launch guided missiles.

Establishment of a completely separate missiles division in 1956.

Now responsibile for nine separate missile projects — including such "veterans" as Nike I (1945 to present) and Sparrow (1947 to present).

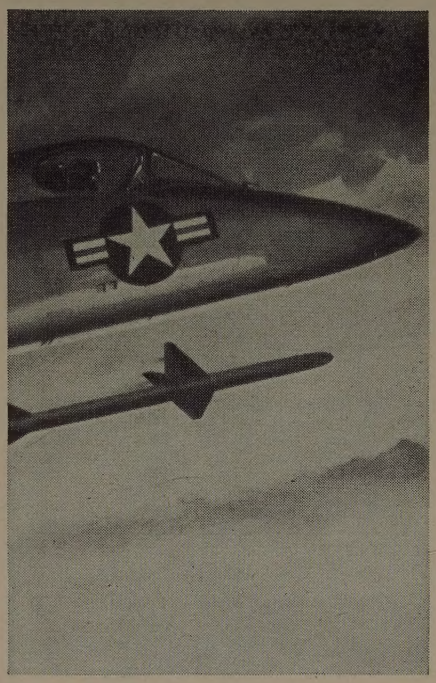
Extensive flight test experience at proving grounds across the country where Douglas engineers are assigned.

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REFERENCES:
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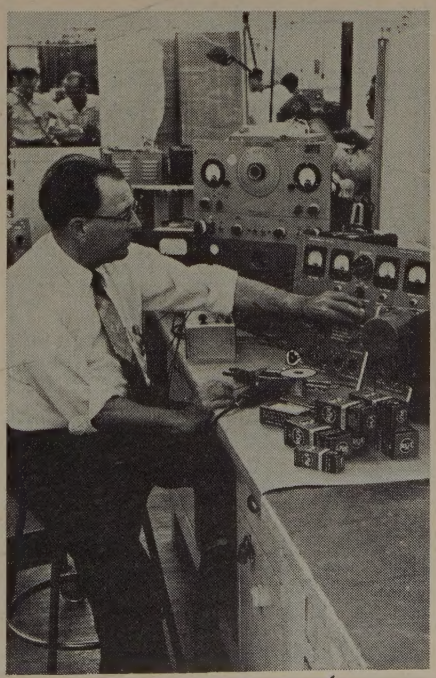
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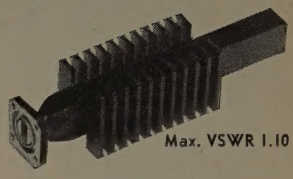
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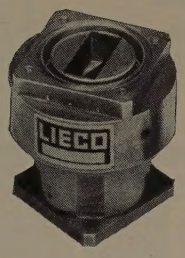
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19MI	26.5–40.0	50	4
19NI	33.0–50.0	40	3½
19PI	50.0–75.0	30	3
19QI	60.0–90.0	25	2½



Max. VSWR 1.10

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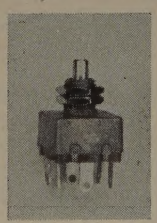
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27HI	7.05–10.0	27MI	16.5–40.0

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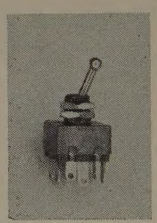
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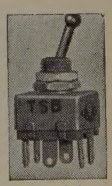
3-Toggle On-Off Model TSK

OTHER SUBMINIATURE SWITCHES, TOGGLE



Model TSA

Model No.	Type
TSA	Single Pole Double Throw
TSB	Double Pole Double Throw
TSC	Single Pole Double Throw, On-Off-On
TSE	Single Pole Double Throw, On-Off-Mom.
TSG	Single Pole Double Throw, Mom-Off-Mom.



Model TSB

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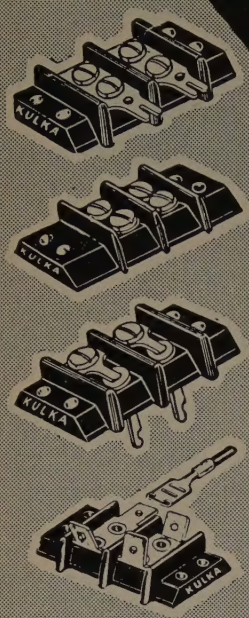
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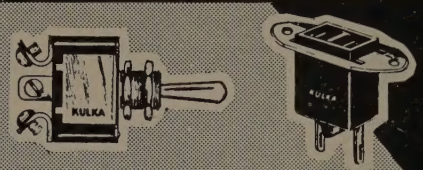
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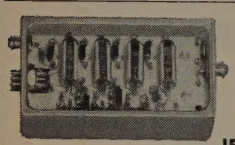
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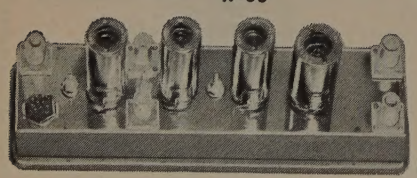
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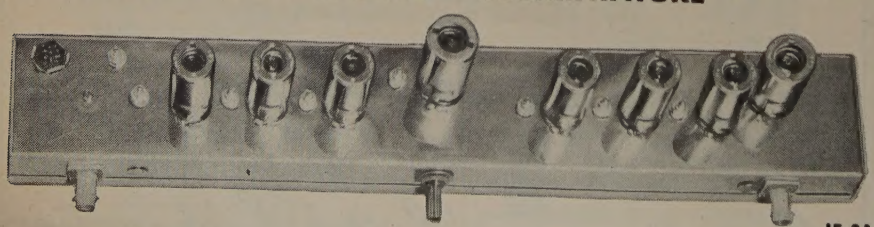
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